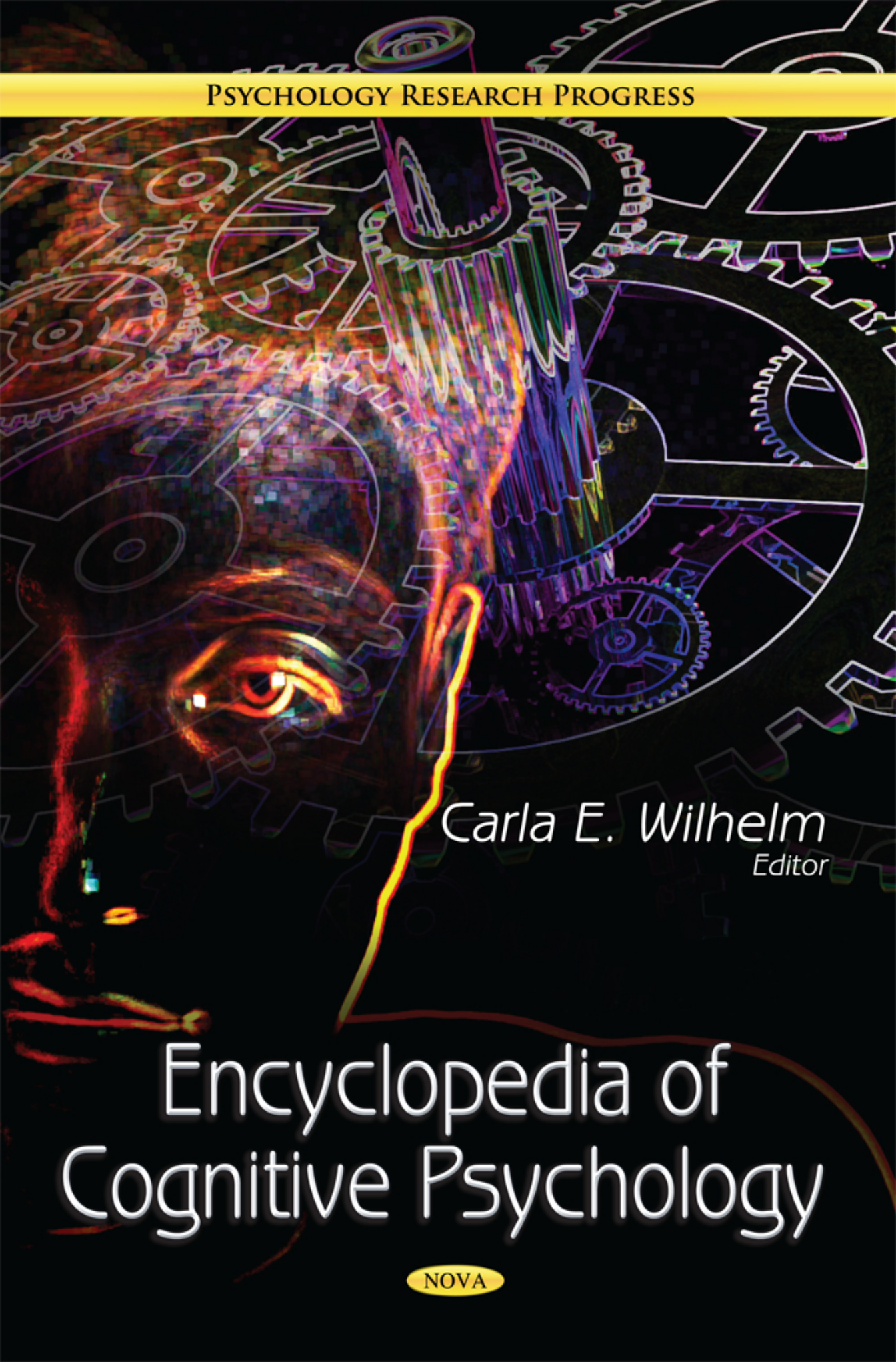




PSYCHOLOGY RESEARCH PROGRESS

Carla E. Wilhelm
Editor

Encyclopedia of Cognitive Psychology

NOVA

PSYCHOLOGY RESEARCH PROGRESS

**ENCYCLOPEDIA OF
COGNITIVE PSYCHOLOGY
(2 VOLUME SET)**

No part of this digital document may be reproduced, stored in a retrieval system or transmitted in any form or by any means. The publisher has taken reasonable care in the preparation of this digital document, but makes no expressed or implied warranty of any kind and assumes no responsibility for any errors or omissions. No liability is assumed for incidental or consequential damages in connection with or arising out of information contained herein. This digital document is sold with the clear understanding that the publisher is not engaged in rendering legal, medical or any other professional services.

PSYCHOLOGY RESEARCH PROGRESS

Additional books in this series can be found on Nova's website under the Series tab.

Additional E-books in this series can be found on Nova's website under the E-book tab.

PSYCHOLOGY RESEARCH PROGRESS

**ENCYCLOPEDIA OF
COGNITIVE PSYCHOLOGY
(2 VOLUME SET)**

CARLA E. WILHELM
EDITOR



Nova Science Publishers, Inc.
New York

Copyright © 2012 by Nova Science Publishers, Inc.

All rights reserved. No part of this book may be reproduced, stored in a retrieval system or transmitted in any form or by any means: electronic, electrostatic, magnetic, tape, mechanical photocopying, recording or otherwise without the written permission of the Publisher.

For permission to use material from this book please contact us:

Telephone 631-231-7269; Fax 631-231-8175

Web Site: <http://www.novapublishers.com>

NOTICE TO THE READER

The Publisher has taken reasonable care in the preparation of this book, but makes no expressed or implied warranty of any kind and assumes no responsibility for any errors or omissions. No liability is assumed for incidental or consequential damages in connection with or arising out of information contained in this book. The Publisher shall not be liable for any special, consequential, or exemplary damages resulting, in whole or in part, from the readers' use of, or reliance upon, this material. Any parts of this book based on government reports are so indicated and copyright is claimed for those parts to the extent applicable to compilations of such works.

Independent verification should be sought for any data, advice or recommendations contained in this book. In addition, no responsibility is assumed by the publisher for any injury and/or damage to persons or property arising from any methods, products, instructions, ideas or otherwise contained in this publication.

This publication is designed to provide accurate and authoritative information with regard to the subject matter covered herein. It is sold with the clear understanding that the Publisher is not engaged in rendering legal or any other professional services. If legal or any other expert assistance is required, the services of a competent person should be sought. FROM A DECLARATION OF PARTICIPANTS JOINTLY ADOPTED BY A COMMITTEE OF THE AMERICAN BAR ASSOCIATION AND A COMMITTEE OF PUBLISHERS.

Additional color graphics may be available in the e-book version of this book.

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA

Encyclopedia of cognitive psychology / editor, Carla E. Wilhelm.

p. cm.

Includes index.

ISBN: 978-1-62618-074-1 (eBook)

Wilhelm, Carla E.

BF201.E53 2011

153.03--dc22

1. Cognitive psychology--Encyclopedias. I.

2011013680

Published by Nova Science Publishers, Inc. + New York

CONTENTS

Volume I

Preface		vii
Chapter 1	A Semantics of the Fundamental Structural Elements of Language, Based on Cognitive Functions: Operational Semantics <i>Giulio Benedetti</i>	1
Chapter 2	A New Perspective on Human Consciousness <i>Giorgio Marchetti</i>	63
Chapter 3	Illusory Perceptions and Memories: What Is the Tie That Binds? <i>Timothy N. Odegard, James M. Lampinen and Emily A. Farris</i>	117
Chapter 4	A New Methodology to Assess Individual Differences in Spatial Memory: The Computer-Generated Version of the Reorientation Paradigm <i>Luciana Picuccia, Andrea Bosco, Alessandro O. Caffò, Guido D'Angelo, Emanuela Soleti, Giulio E. Lancioni and Manuela N. di Masi</i>	159
Chapter 5	Pretrial Publicity Affects Juror Decision Making and Memory <i>Christine L. Ruva</i>	197
Chapter 6	TP-Theory as New Perspective on Cognitive Psychology <i>Koji Tanida and Ernst Pöppel</i>	227
Chapter 7	Learning Strategies and Approaches of University Students: The Challenge of the 21 st Century <i>Nora Irene Abate</i>	245
Chapter 8	Cognitive Rehabilitation in Middle-Aged Alzheimer Patients <i>Elisabetta Farina and Fabiana Villanelli</i>	273
Chapter 9	The Cognitive Effects of Anxiety on Sexual Arousal <i>Philippe Kempeneers, Romain Pallincourt and Sylvie Blairy</i>	295
Chapter 10	Limits to General Expertise: A Study of in- and out-of-Field Graph Interpretation <i>Wolff-Michael Roth</i>	311

Volume II

Chapter 11	Conceptual Combination: Models, Theories, and Controversies <i>Bing Ran and P. Robert Duimering</i>	349
Chapter 12	A Test of the Cognitive Theory of Obsessions: Study of Internal Structure and Validity of the Obsessive Beliefs Questionnaire in Italian Individuals <i>Stella Dorz, Caterina Novara, Massimiliano Pastore, Ezio Sanavio, Luigi Rocco Chiri and Claudio Sica</i>	375
Chapter 13	Haptic Abilities in Infancy and Their Relation to Vision: A Review <i>Arlette Streri</i>	405
Chapter 14	Emotional Modulation of Selective Attention: Experimental Evidence in Specific Phobia <i>Marlen Figueroa, Sonia Rodríguez-Ruiz, José L. Mata, Walter Machado-Pinheiro and Jaime Vila</i>	433
Chapter 15	The Moderating Effect of Switching Costs in Consumers' Relationship Dissolution: A Cross-Cultural Analysis <i>Carmen Antón Martín and Carmen Camarero Izquierdo</i>	465
Chapter 16	Tripartite Concepts of Mind and Brain, with Special Emphasis on the Neuroevolutionary Postulates of Christfried Jakob and Paul MacLean <i>Lazaros C. Triarhou</i>	489
Chapter 17	Category-Specific Semantics in Alzheimer's Dementia and Normal Aging? <i>Keith R. Laws, Tim M Gale, F. Javier Moreno-Martínez, Rebecca L. Adlington, Karen Irvine and Sunil Sthanakiya</i>	515
Chapter 18	Preverbal Category Formation: The Role of Real-World Experience <i>Birgit Träuble, Lysett Babocsai and Sabina Pauen</i>	537
Chapter 19	Peripheral Responses Elicited By Motor Imagery: A Window on Central and Peripheral Nervous System Relationships through Motor Commands Inhibition <i>C. Collet and A. Guillot</i>	551
Chapter 20	Rationality: The Desire for an Absolute without a Cause <i>Todd McElroy, Jacob Conrad and Dominic Mascari</i>	567
Chapter 21	The Cognitive Effects of Anxiety on Sexual Arousal <i>Philippe Kempeneers, Romain Pallincourt and Sylvie Blairy</i>	579
Index		595

PREFACE

Chapter 1 - In this chapter, the author provides a brief introduction to a completely new theory in Semantics, *Operational Semantics* (OS), which concerns the meanings of the *basic linguistic elements* that are indispensable for any linguistic expression, that is, mainly the “grammatical” words (conjunctions, prepositions, articles, most pronouns and corresponding adjectives, fundamental verbs like “to be”, “to have” etc, the main adverbs) and, in the large number of languages that have a more or less rich morphology, almost all morphemes. OS differs significantly from other existing theories. In fact, in linguistics several of these basic elements are often considered to have a *complex* meaning and, in some cases, to be *polysemous* (such as some prepositions/cases and some verbs). Nevertheless, *the words that designate them are among the first that children learn, and unique*. OS is a systematic theory about the meaning of these linguistic elements, which it considers, *in agreement with such facts*, as having a *simple* and (substantially) *unique* meaning.

The fundamental presupposition of OS is that the meanings of such linguistic elements are essentially *sequences of elemental mental operations, amongst which the ones of attention play a key role*. The author proposes a list of these elemental mental operations and shows how it is possible, by basing ourselves on these, to account for the meanings of the aforesaid linguistic elements. *A new theory*, which lies between linguistics and cognitive psychology, derives from this. This theory also allows us to define fundamental concepts of linguistics (such as “noun”, “subject”, “object” etc) in a simple and clear way and propose new solutions for some other problems in linguistics and psycholinguistics.

In the last part of the chapter, the author also mentions a possible short-term practical application of OS, i.e. a device to improve the quality of machine translation, and highlights the limits of OS.

Chapter 2 - The aim of this paper is to provide an answer to a fundamental question concerning human consciousness: how can we explain the phenomenal quality of our conscious experiences? It is argued that the first-person perspective is the most suitable one to deal with conscious experience. Accordingly, a model is developed on the idea that the person emerges as an entity from the organism’s continuous application of its own energy to itself. The model is composed of two main parts: the perceptual system and the schema of self. The perceptual system makes it possible for an organism to be conscious, whereas the schema of self provides the rules that make an organism perceive, move, act, behave, and live in general. The stream of consciousness arises from the uninterrupted interaction of these two systems. The core part of the model is represented by attention. Attention, which is the

activity the organism can perform thanks to the nervous energy supplied by the organ of attention, gives the organism the possibility of performing actions capable of directly varying the organism's state of nervous energy. It is this variation that constitutes the phenomenal aspect of consciousness. When acting, the organism can directly experience and feel its actions and the results of its actions, thus making possible the delimitation and emergence of the person.

Chapter 3 - Research suggests that both perceptual and memory representations involve discrete features that are bound together to form coherent wholes. The process which combines features into unified wholes is known as feature binding and is seen as an integral part of conscious experience. Errors occur in both perceptual and memory based feature binding. In perception, errors in feature binding produce illusory conjunctions. For instance, participants presented with a red triangle and a blue square will sometimes mistakenly perceive a blue triangle next to a red square. Illusory conjunctions demonstrate the importance of attentional resources in the binding of features in perception. Feature binding errors also occur in memory. Such errors are known as memory conjunction errors. For example, participants presented with words such as *blackmail* and *jailbird* will sometimes mistakenly remember the word *blackbird*. Such findings provide evidence for the reconstructive nature of human memory. Considerable research has established the existence and subjectively compelling nature of these sorts of errors. Moreover, relatively well established theoretical literatures exist in an attempt to account for both illusory conjunctions and memory conjunction errors. However, to date, no systematic attempt has been made to draw parallels and connections between these two literatures. The purpose of the present chapter is to demonstrate similarities and differences between these two types of errors and to provide a unified comprehensive account of both types of errors. In the process the authors hope to elucidate how feature binding can be used to better understand both perception and memory.

Chapter 4 - Gender and age are assumed to affect spatial performance. However, systematic attention to gender differences across life-span remains sparse. This paper provides an overview on behavioural changes in human reorientation as effect of gender and age. A total of 340 healthy participants, balanced by gender, were divided into three groups (166 children, 72 young adults, 102 aged adults) and engaged in a virtual version of the Reorientation Paradigm. The task consisted of a learning phase, in which participants acquired spatial information about the position of a target, and of a testing phase, in which participants searched for the hidden target. Performances of the three groups have been compared in: (a) an environment with layout information only, (b) an environment with both layout and featural information, and (c) an environment with featural information only. Accuracy in testing phase (i.e. number of correct searches) and navigation style (i.e. measured as time spent and path lengths, in both learning and testing phase) were evaluated. Results showed an age related effect in all the measures provided. On average, children and aged adults spent more time and cover longer distance with respect to young adults, in both learning and testing phase. In addition, the ability to evaluate spatial information is not completely achieved in children and tends to decrease in aged adults. The interaction between gender and age showed that gender related differences are absent in childhood, but became considerable in adulthood and remain stable in old age. These results are in line with an explanation of gender-related differences in spatial cognition founded on the interaction between biological and environmental/cultural factors.

Chapter 5 - Pretrial publicity (PTP) has been found to have a biasing effect on jury decision making. This chapter explores how research and theory in cognitive psychology has been used to examine the mechanisms responsible for PTP's biasing effects on jury decisions. This research can assist the courts in finding effective remedies for PTP bias. The chapter explores how exposure to PTP is similar to exposure to misinformation in the reversed suggestibility paradigm and that memory for the trial can be affected by misinformation (PTP) presented before the trial (Lindsay & Johnson, 1989; Rantzen & Markham, 1992). The chapter will also review research and theory examining whether memory errors (e.g., source misattributions) and biases of individual jurors are likely to be corrected by jury members during deliberations. A review of relevant literature is followed by the presentation of two research studies. The first study explores whether deliberation reduces the biasing effects of PTP by comparing group (jury) and individual (juror) decisions using the nominal group method. This study also explores whether jurors who are exposed to PTP are likely to misattribute information presented only in the PTP to the trial. The second study explores the effects of both negative (anti-defendant) and positive (pro-defendant) PTP on juror decision making. Both studies suggest that even if jurors are instructed not to use information contained in the PTP to make decisions about guilt, they may be unable or unwilling to do so because of source memory errors and their perceptions of the defendant and trial attorneys. This research also suggests that jury deliberations can increase (polarize) juror bias and therefore, cannot be counted on to remedy the effect of PTP on jury decision making.

Chapter 6 - Recently, the fact that there is anticipation before cognition in the brain processing is elucidated by brain science, although human behavior has been explained as cognition-judgment-operation loop. The TP-theory (Temporal Predictive behavior model proposed by Tanida and Pöppel in 2006) is a model which applies anticipation-operation-comparison loop as new information processing with temporal frame to human behavior including automobile driving. Why is driving referred? Driving an automobile is an example of a goal-directed activity with high complexity in which different behavioral elements have to be integrated and brought into a sequential order. On the basis of the reafference principle and experimental results on temporal perception and cognitive control, the authors propose a hierarchical model of driving behavior which can also be adapted to other goal-directed activities. Driving is conceived of as being controlled by anticipatory neuronal programs; if these programs are disrupted by unpredictable stimuli which require an instantaneous reaction, behavioral control returns after completion of the reactive mode to the anticipatory mode of driving. In the model different levels of anticipation windows are distinguished which, however, are interconnected, in a bi-directional way: A. Strategic level with a representation of the driving activity from the beginning to reaching the final goal; B. Segmented tactical level with the sequence of necessary milestones to reach the goal, which are characterized by adaptive scenarios; C. Maneuver – in general operational level, where actions like passing another car or keeping a lane are controlled; this level represents learned activities which have become automatized; D. Short term integration level of two to three seconds, which allows immediate anticipations; this temporal window represents the subjective present; E. Synchronization level for sensory motor control and complexity reduction within neuronal assemblies which allows the creation of mental content and consciously available categories. A flow diagram schematically describes different driving situations stressing the anticipatory mode of control. As mentioned before, this model is able

to apply to riding a motorcycle or a bicycle, cooking, gardening, DIY etc.. This chapter gives the general explanation about the TP-theory.

Chapter 7 - This work is based on an investigation on the used strategies of learning, by the students who attend the last year of the race of Psychology of the National University of Tucuman, Argentine Republic. In the different educative levels numerous problems in the learning processes have been observed. The mental approach provides the suitable theoretical model to include/understand and to analyze the learning strategies. The work hypothesis was that the general average of the qualifications obtained by the students of fifth year of the race of Psychology is related to the use of learning strategies: acquisition, codification, recovery and support. The examples are based with the application of a scale of learning strategies, (ACRA) of Roman and Gallego (1994), in a random sample of students who attended fifth year in the race of Psychology. The conclusions allow to affirm that some students preferably used the strategies of acquisition and codification, with a way to learn limited the requirements of the task, that allowed them to approve the subject. However, the other used all the strategies, preferably those of recovery and support. That is to say, that besides learning knows like doing it. The results allowed to verify the hypothesis and to establish the positive and significant relation, between the averages of the qualifications and the strategies of learning. The importance of these findings will allow, to reframe the processes of education-learning with a view to the formation of a critical, reflective and strategic student. Key words: Learning Strategies of learning-Education

Chapter 9 - Anxiety and sexual arousal have often been considered as incompatible. Since the end of the 20th Century, however, researches have impaired theories centred on the inhibitory effect of the stress and on peripheral explanations; they rather focus attention on the complexity of the relations between the two states and on cognitive mechanisms.

Now sexual arousal tends to be regarded as a complex response that requires the convergent interpretation of internal and external stimuli. Anxiety may have different effects on this process, sometimes neutral, sometimes facilitating and sometimes inhibitory.

On the one hand, anxiety can trigger a vegetative emotional reaction that may be associated to a concomitant erotic stimulation. Thus, anxiety facilitates the sexual response: this can be called a *priming effect*. This effect is regularly observed in labs, mainly among women. It likely also works in certain compulsive sexual behaviours or, more commonly, in those numerous persons that report being sexually aroused when stressed.

On the other hand, anxiety can cause a massive irruption of non erotic cues in working memory. Therefore, cognitive function available for treating erotic stimuli is diminished and sexual response is impaired. This is an effect of *cognitive interference*. A trait called *erotophobia* could be regarded as a vulnerability factor to cognitive interference. Erotophobic subjects are characterized by a trend to focus upon danger-related information when they are in a sexual situation and by a higher risk of sexual dysfunction

Chapter 10 - Graphs are pervasive features in professional science journals, which makes graphing one of (if not the) most important practice (and therefore skill) of professional science. Scientists generally are expected to be experts in graphing. Contrary to this expectation, recent investigations showed that scientists asked to interpret graphs from introductory-level textbooks in their own field did not at all exhibit expert-like behavior. The present study was designed to understand better the nature of graphing practices among professional scientists. I investigated the similarities and differences in scientists' interpretation of structurally identical in-field and out-of-field graphs. Seventeen physicists

interpreted 3 graphs that were derived from entry-level university textbooks in ecology—for cross validation purposes, these were the same graphs used in an earlier expert-expert study—and 3 structurally identical graphs from the field of physics. My analyses reveal that the graphing expertise of physicists is limited even within their field. Their graph interpretations are highly idiosyncratic and contingent both within and across content domains. Common to the interpretive practices on in-field and out-of field graph was that scientists interpreted them according to the purposes of (a) graphing in science in general and (b) those of the graph interpretation interview session specifically. In using varying resources and in experiencing breakdowns, they exhibited considerable differences between in-field and out-of-field graph interpretations. Working on in-field graphs, they drew on general knowledge and prior experiences from their professional life, whereas in the context of out-of-field graph interpretations, scientists provided verbal equivalents for the visible, surface features of the line graphs and drew on mundane everyday life experiences to explicate them.

Chapter 11 - This paper provides a comprehensive and critical review of the major theories and models of conceptual combination, by highlighting agreements and controversies in the literature, and identifying future directions for research. The review summarizes the basic arguments of ten major models and then presents an analytical framework to compare and contrast these models along four dimensions: (1) the causal role of schemata in the model; (2) the role of cognitive harmony or consistency in the model; (3) the pragmatic orientation in the model; and (4) the explanatory scope of the model. The review identifies areas of agreement and disagreement among the various models and theories and calls for a synthesis theory to address various theoretical weaknesses and empirical gaps in the current explanations.

Chapter 12 - *Background*: A widely-held belief is that obsessions arise from the misinterpretation of normal intrusive thoughts (e.g., misinterpreting unwanted harm-related thoughts as a sign that one is going to act on them). This leads the person to perform compulsions such as repeated checking. Misinterpretations are said to arise from various types of beliefs (e.g., the belief that thoughts inevitably give rise to actions). In support of this theory, some studies have shown that such beliefs are correlated with obsessive-compulsive disorder (OCD). The Obsessive Beliefs Questionnaire (OBQ) is an 87-item self-report instrument developed by an international group (Obsessive Compulsive Cognitions Working Group - OCCWG) to assess cognitions thought to be relevant to the etiology and maintenance of obsessions and compulsions. The OBQ contains six scales measuring as many dysfunctional beliefs: Inflated responsibility, Overimportance of thoughts. Excessive concern about the importance of controlling one's thoughts, Overestimation of threat, Intolerance of uncertainty, and Perfectionism. To date, the OBQ has been mainly studied in clinical and non-clinical individuals drawn from English-speaking populations. Results showed that the questionnaire generally has a good internal consistency (Cronbach alpha coefficients equal or above .80) and an adequate test-retest reliability. However, three OBQ domains (Tolerance of uncertainty, Overestimation of threat and Perfectionism) appeared to be OCD-relevant but not OCD-specific, since they did not discriminate individuals with OCD from anxiety controls. In addition, correlations with measures of OCD symptoms, mood and worry, showed that the OBQ was as highly correlated with the non-OCD symptom measures (anxiety, depression and worry) as it was with OCD ones. Lastly, an exploratory factor analysis revealed that a three-factor solution best explained the internal structure of the questionnaire. In summary, such

results raise doubts about the cognitive theory of obsessions and compulsions even though more studies are needed before the theory can be reformulated.

Aims and method: The present paper reports on the Italian validation of the OBQ: the extent to which the psychometric properties of the OBQ (and, in particular, its internal structure) are equivalent to the original one may reveal interesting clues about the structure of beliefs and their relationships with OCD symptoms. The OBQ was administered to 752 Italian undergraduate students along with the Padua Inventory (a measure of OCD symptoms), the Beck Anxiety Inventory and the Beck Depression Inventory.

Results: exploratory factor analyses did not replicate the original six-factor structure of the OBQ, nor the three-factor structure obtained by analyzing the original American sample. A confirmatory factor analysis revealed that the Italian version of the OBQ was best described by five factors and 46 items. In particular, the Italian version was characterized by the absence of the intolerance of uncertainty and overestimation of threat scales, and by the subdivision of the responsibility scale into the scales responsibility for harm and responsibility for omission. Internal consistency and temporal stability of the five scales of Italian version of the OBQ was satisfactorily; intercorrelations among the five scales were moderately high. Results from convergent and discriminant validity revealed that Perfectionism, Responsibility for harm and Control thoughts resulted good predictors of OCD symptoms, whereas Responsibility of omission and Importance of thoughts did not predict OCD symptoms at all in a regression analysis model.

Findings were discussed in terms of relevance and specificity of cognitive constructs to OCD symptoms.

Chapter 13 - The old debate concerning the primitive unity (nativist conception) or the separation (empiricist conception) of senses at birth has been revived in recent years, as difficulties in the methodology of studying perception in babies were overcome. How can babies know by touch? To answer to this question, three aspects of human infants' haptic abilities are presented in this review. How the young babies: 1. Perceive information and form a perceptual representation of objects derived from the hands alone; 2. Transfer this information to vision in an intermodal process; 3. Obtain haptic knowledge in limited exploration conditions as they do in the visual modality? Using a habituation/dishabituation procedure, experiments have revealed that infants, from birth, are able to discriminate object shapes in the manual as well as in the visual mode. These abilities are a prerequisite for understanding the relations between the haptic and the visual sensory modalities in cross-modal transfer tasks. Using an intersensory successive preference procedure, several experiments provided evidence for cross-modal recognition from touch to vision from birth. The links however are limited, partial and not reciprocal. Nevertheless, adaptations of paradigms for studying visual cognition reveal that the haptic system shares some amodal mechanisms with the visual modality. Despite various discrepancies between both modalities, conceiving the world is possible with the hands as well as the eyes soon after birth.

Chapter 14 - Empirical research has demonstrated that emotional information is rapidly and extensively processed and that assessment of that information takes place automatically, outside of conscious awareness (Edelstein & Guillath, 2008). This processing bias presumably occurs in conditions that require the healthy or anxious individual to scan the environment for information (Mathews & MacLeod, 1994). So, the attention is captured by, or shifted towards, emotionally relevant stimuli. Multiple factors can explain how emotion drives attention. This chapter throws light on some of these factors.

Chapter 15 - The current work analyzes the impact of deficiencies in firms' policies on the customers' intent to break the relationship and the moderating role of switching costs. The work is developed in the context of car insurance services. Concretely, in this context, we differentiate two legal situations that can influence the dissolution process: the countries where consumers comply with the legal obligation to take out car insurance and the countries where consumers feel that the legislation is more permissive and fail to comply with the legal obligation. A comparison of consumers from these two contexts (Spanish and Venezuelan consumers) allows us to derive some conclusions.

Chapter 16 - The 'triune brain', conceived by Paul D. MacLean (1913–2007) in the late 1960s, has witnessed more attention and controversy than any other evolutionary model of brain and behavior in modern neuroscience. Decades earlier, in his book *Elements of Neurobiology* published in 1923 in La Plata, Argentina, neurobiologist Christfried (Christofredo) Jakob (1866–1956) had formulated a 'tripsychic' brain system, based on his deep understanding of biological and neural phylogeny. In a historical context, 1923 was also the year of publication of Sigmund Freud's *The Ego and the Id*, whereby the founder of psychoanalysis solidified his tripartite model of the mental apparatus. Tripartite systems of the human mind have been surmised since Plato and Aristotle; they continue to our era, an example being Robert J. Sternberg's triarchic theory of human intelligence. In view of the fact that both Jakob and MacLean invested a considerable part of their long and distinguished careers studying comparative, and particularly reptilian neurobiology, the present article revisits their neuroevolutionary models, underlining the convergence of their anatomical-functional propositions, in spite of a time distance of almost half a century.

Chapter 17 - Category-specific deficits represent the archetypal illustration of domain-specific cognitive processes. These deficits describe individuals who, following certain types of neurological damage show dissociations in their ability to recognise and name exemplars from within specific domains e.g. living or nonliving things. Cases described over the past 25 years have formed a pivotal foundation for the development of models describing the structure and organisation of lexical-semantic memory. In this chapter, we review the evidence on whether category deficits in AD are consistent with the loss of isolated categorical information, an artefact of confounding psycholinguistic variables (e.g. age of acquisition, word frequency, and familiarity) or an exaggeration of some pre-existing normal cognitive difference. Finally, we present emerging evidence that female AD patients show worse semantic memory impairment than male patients. In this context, we discuss a possible role for the apolipoprotein E (APOE) $\epsilon 4$ allele, which is associated with a greater probability for developing AD in women and impacts more on the cognitive performance of healthy women than men.

Chapter 18 - Studies on categorization using the object-examination task (OET) show that infants carry out a global-to-basic level shift in their second half of their first year of life. What underlies performance in the OET still remains unclear, however. Following one view, infants in an OET activate previously acquired knowledge about real-world exemplars. This suggests that categorization performance in the OET should vary with the amount of experience infants have with real-world exemplars displayed by the experimental material. The present studies test this hypothesis, by comparing the categorization performance of infants who do not have regular contact to cats or dogs (Experiment 1) with the performance of infants who live with a cat or a dog at home (Experiment 2). Analyses based on data from $N = 80$ 9- and 11-month-old infants reveal that 11-month-olds who have experience with

cats or dogs make a clear categorical distinction whereas infants without such experiences do not show any categorization response. This set of findings suggests that experience with real-world animals influences performance of infants participating in an OET providing a basic-level contrast within the animate domain.

Chapter 19 - The aim of this paper was to examine the way in which motor commands addressed to the somatic and autonomic effectors are inhibited during Motor Imagery (MI). Three experiments are described, each referring to specific motor requirements. The first requested the participants to lift a weighted dumbbell with their preferential hand (flexion of the forearm), while seating in a chair. In the second task, the participants were asked to perform 3 consecutive vertical jumps on a force plate, while the third was a coincidence anticipation task requiring intercepting a table-tennis ball thrown by a robot, with the inner side of the hand. All were performed under actual vs. mental practice. In the first experiment, a subliminal muscular activity was recorded during MI, which was specific to the type of muscle contraction. In the second experiment, MI was shown to reduce postural sway amplitude in the standing position on both the anterior-posterior and the lateral axes compared to the control condition (standing motionless on the force plate). In the third experiment, the autonomic responses recorded during MI showed the same pattern that those recorded during actual movement. While performing MI, the 3 motor commands were thus shown to be affected differentially with reference to somatic and autonomic inhibition. Experiment 1 provided evidence that direct voluntary commands are not fully inhibited during MI. Although this process remained not solved, it is supposed at organising peripheral effectors during the preparation phase, as for the actual execution of the movement. The incomplete inhibition of motor commands was confirmed by the second experiment as postural adjustments were not inhibited. Accordingly, MI may thus have a more limited effect on automatic sensori-motor processes usually associated to voluntary motor commands. This was confirmed in the third experiment in which autonomic nervous system regulations were preserved during MI. These findings should be used in MI program (in sport training or clinical rehabilitation), as incomplete inhibition may give feedback information to the central nervous systems. Further research should nevertheless investigate the processes of somatic motor commands inhibition.

Chapter 20 - Friedrich Nietzsche depicts us as creatures bound by an irrational determinism. This ascription to irrational forces is commonplace and many, if not most, people adhere to this belief. Such a belief is not surprising in light of how the unconscious was, for many years, thought of as a mythical, dark place where sadistic urges and sexual perversions resided. These terrifying forces, however, were reportedly kept at bay by a surrealistic chasm that lies just between conscious realization and the dark abode of unbounded hedonistic acceptance. Not a pretty picture considering that the unconscious constitutes a large part of what it means to be human. Taking such a position, as some do, seems troubling to those trying to further a scientific understanding of human psychology. Practically speaking, if we are bound by such a circumstantial existence then why strive for more? In other words; why should we place such effort in making better decisions when the choices that we make will inevitably be tainted by irrational concomitance with unconscious forces? In this chapter we take a very different view, following a broad perspective that portrays predecisional thought as one of cooperation between two forces working toward a common outcome. Rather than ascribing our fate to the inescapable void of irrational fallibility, we make the case that decision choice can be better understood by approaching it

as a complementary superordinate process and perhaps, at times, a contradictory process. Nevertheless, the essence of the decision process is always an interactive product of conscious and unconscious influences. We believe that furthering the understanding of this dualistic pairing will allow us to achieve a better understanding of decision processing and allow for more optimal decision making.

Chapter 21 - Anxiety and sexual arousal have often been considered as incompatible. Since the end of the 20th Century, however, researches have impaired theories centred on the inhibitory effect of the stress and on peripheral explanations; they rather focus attention on the complexity of the relations between the two states and on cognitive mechanisms.

Now sexual arousal tends to be regarded as a complex response that requires the convergent interpretation of internal and external stimuli. Anxiety may have different effects on this process, sometimes neutral, sometimes facilitating and sometimes inhibitory.

On the one hand, anxiety can trigger a vegetative emotional reaction that may be associated to a concomitant erotic stimulation. Thus, anxiety facilitates the sexual response: this can be called a *priming effect*. This effect is regularly observed in labs, mainly among women. It likely also works in certain compulsive sexual behaviours or, more commonly, in those numerous persons that report being sexually aroused when stressed.

On the other hand, anxiety can cause a massive irruption of non erotic cues in working memory. Therefore, cognitive function available for treating erotic stimuli is diminished and sexual response is impaired. This is an effect of *cognitive interference*. A trait called *erotophobia* could be regarded as a vulnerability factor to cognitive interference. Erotophobic subjects are characterized by a trend to focus upon danger-related information when they are in a sexual situation and by a higher risk of sexual dysfunction.

Versions of chapters 1 through 9 were also published in *Cognitive Psychology Perspectives*, edited by G. Salvati and V. Rabuano, published by Nova Science Publishers, Inc. They were submitted for appropriate modifications in an effort to encourage wider dissemination of research.

Versions of chapters 10 through 21 were also published in *Cognitive Psychology Research Developments*, edited by Stella P. Weingarten and Helena O. Penat, published by Nova Science Publishers, Inc. They were submitted for appropriate modifications in an effort to encourage wider dissemination of research.

Chapter 1

A SEMANTICS OF THE FUNDAMENTAL STRUCTURAL ELEMENTS OF LANGUAGE, BASED ON COGNITIVE FUNCTIONS: OPERATIONAL SEMANTICS

Giulio Benedetti

Pisa, Italy

ABSTRACT

In this chapter, the author provides a brief introduction to a completely new theory in Semantics, *Operational Semantics* (OS), which concerns the meanings of the *basic linguistic elements* that are indispensable for any linguistic expression, that is, mainly the “grammatical” words (conjunctions, prepositions, articles, most pronouns and corresponding adjectives, fundamental verbs like “to be”, “to have” etc, the main adverbs) and, in the large number of languages that have a more or less rich morphology, almost all morphemes. OS differs significantly from other existing theories. In fact, in linguistics several of these basic elements are often considered to have a *complex* meaning and, in some cases, to be *polysemous* (such as some prepositions/cases and some verbs). Nevertheless, *the words that designate them are among the first that children learn, and unique*. OS is a systematic theory about the meaning of these linguistic elements, which it considers, *in agreement with such facts*, as having a *simple* and (substantially) *unique* meaning.

The fundamental presupposition of OS is that the meanings of such linguistic elements are essentially *sequences of elemental mental operations, amongst which the ones of attention play a key role*. The author proposes a list of these elemental mental operations and shows how it is possible, by basing ourselves on these, to account for the meanings of the aforesaid linguistic elements. *A new theory*, which lies between linguistics and cognitive psychology, derives from this. This theory also allows us to define fundamental concepts of linguistics (such as “noun”, “subject”, “object” etc) in a simple and clear way and propose new solutions for some other problems in linguistics and psycholinguistics.

In the last part of the chapter, the author also mentions a possible short-term practical application of OS, i.e. a device to improve the quality of machine translation, and highlights the limits of OS.

Keywords: mind, mental operations, consciousness, attention, thought, language, Italian Operational School, operational semantics, linguistics, psycholinguistics, neurolinguistics, semantics, grammar, philosophy, cognitive psychology, neurobiology

1. INTRODUCTION

Among the various aspects of what we call “human consciousness” (Baars 1988; Bieri 1992; Chalmers 1996; Churchland, Sejnowski 1992; Damasio 1994; Dennett 1991; Edelman 1989, 1992; Searle 1984, 1994; Stich 1996; Zeman 2001), language has been studied from various points of view and its study has produced a great deal of results. Nevertheless, its most important (from a certain point of view) aspect, that is, semantics (since language is the expression of *meanings*), has proved to be the most problematic [Chomsky 1987, Bloomfield 1933, Lehmann 1992]. In this paper, I shall consider language right from the point of view of semantics, introducing a radically new theory in this field. I call this theory *Operational Semantics* (OS). Here, I shall provide a brief exposition of it.

This chapter has been conceived to be read by as wide a public as possible. Therefore, a specialised foundation has been avoided.

2. THE ORIGINS OF OPERATIONAL SEMANTICS

OS partly coincides with Silvio Ceccato’s (1914-1997) thought, partly is an innovative development of this, partly is very different. Ceccato’s thought started developing in the 1950s and reached its full maturity in the 60s and 70s [Ceccato 1964, 1966, 1968, 1969, 1970, 1972, 1974; Ceccato, Zonta 1980]. Ceccato used various names for the theories that made up his thought. The name *Operational Methodology* (OM) is the one that has prevailed in his School, the *Scuola Operativa Italiana* (SOI) [Italian Operational School].

Even though Ceccato was well-known in Italian philosophical circles since the 40s and even though he directed important projects involving the application of his theories (one of the very few European projects of machine translation and the only one in Italy in the first phase of research in this field [funded by USA Air Force, 1959-66; described in Ceccato 1969]; the project of the so-called “mechanical reporter”, a machine that had to be able to observe and to describe a scene made up of seven objects arranged in various ways on a stage [Italy National Research Council, 1958-66; described by Ceccato 1969]), his thought has had very little diffusion. This can be due to various reasons. It is impossible to examine them in detail here, but we can mention the main ones: a) Ceccato, even if he started from the field of philosophy, contrasted sharply with it, introducing his thought as something radically opposite to the whole philosophic tradition¹; b) he had anti-academic attitudes and did not want to form a real school; c) he maintained an excessively radical (in my opinion) constructivism and a relativism that weaken values; d) sometimes he used a difficult language. Nevertheless, I believe that the work of Ceccato and his School [Glaserfeld E. von

¹ This substantial diversity from the whole philosophical tradition is however essentially real: Ceccato’s thought presents vague analogies only with part of Kant’s philosophy and with the operationalism of H. Dingler and that of P. Bridgman.

1989, 1998; Parini 1996; Vaccarino 1988, 1997, 2000; Amietta, Magnani 1998], even if it needs an in-depth critical revision, includes many original and very valuable ideas and intuitions, which deserve to be taken into consideration again and developed. This is precisely where I have focused my work ever since the second half of the 90s [Benedetti 1999, 2004, 2005a,b]. In the early 90s, another researcher from the *SOI*, Giorgio Marchetti began a very remarkable critical revision and development of Ceccato's thought [Marchetti 1993, 1997, 2001, 2003, 2005a, 2006, 2009]. Since 2003, there has been a tight collaboration between Marchetti and myself.

In the following treatment, there is the problem of distinguishing Ceccato's original theories from those of the author. A complete and precise distinction here is not possible due to lack of space: for such a distinction, I can do nothing else but refer the reader to the bibliography [Ceccato 1964, 1966, 1968, 1969, 1970, 1972, 1974, 1996; Ceccato, Zonta 1980; Ceccato, Oliva 1988]. Nevertheless, in the main text or in the notes, I shall indicate which are Ceccato's main original theses and which are the author's. When this is not provided, the thought exposed generally derives from Ceccato's, but with possible differences. The foundation of the exposition is the author's own and differs entirely from Ceccato's.

3. THE FUNDAMENTAL THESES OF OPERATIONAL SEMANTICS

The best way to introduce OS is starting from a concrete example. That is, to take a sample of language at random and think over the meaning of the words that form it. It is important to note that, from the point of view that I am about to express, we may choose *any* sample of language, in *any* language, and the result will be always the same. As a sample of language, let's take the beginning of one of the most famous books in the world: Pinocchio.

Once upon a time there was...

— A king!— my small readers will say at once.

No, children, you are wrong. Once upon a time there was a piece of wood.

It was not a luxury wood, but a simple stack piece, one of those pieces we use to put in stoves and fireplaces in winter to light fire and to heat rooms.

[translation from Italian is the author's own]

Every discrete element of language, that is, every word, designates at least one meaning (in many languages however, many single words designate more than one meaning together, like, for instance: the basic meaning of a noun plus the plural; a verb and its tense, mood and person; etc). Therefore, each word designates one or more "atoms" of thought. Let's ask ourselves what these "atoms" are, what their nature is. As far as their nature is concerned, it seems that the meanings of words can be divided into at least two main classes.

1) In the passage we have chosen, the words "children", "wood", "stack", "stoves", "fireplaces", "winter", "[to] light", "fire", "[to] heat", "rooms" seem to designate something *physical* (apart from the endings that indicate the plural). It is easy to realise that there are so many of these words that they probably make up most of the lexicon of any language. Therefore, there is a big class of words that make an *evident and specific reference to something physical*.

2) In the passage chosen, there are then the following words: the verbs “to be” and “to have”, the article “a”, the prepositions “upon”, “at”, “of”, “in”, “to”, the demonstrative adjective “those”, the negations “no” and “not”, the conjunctions “and” and “but”, the numerals “once” and “one”, the adverb “there” and the morpheme “-s” (or “-ren”, in “children”), which indicates the plural. These words (or morphemes: morphemes instead of words are used in other languages) seem to be *clearly different* from those in class 1. In fact, unlike the words in class 1, these words *do not* seem to refer (or refer only) to something physical. Although they are certainly often used to describe the physical word, they do not seem by any means to *necessarily* and *specifically* refer to something physical. If, for example, instead of saying “*this* stone”, “*two* trees”, “*all* the grass” (phrases where the words in italics refer to physical things), we say “*this* problem”, “*two* considerations”, “*all* his thought” (phrases where there is no reference to something physical), the meaning of the words “this”, “two” and “all” does not seem different at all.

In a language, items of this kind are all the “grammatical” words or morphemes, that is:

- *prepositions*² (with, of, to, at, from, by, in, for, on, between, among etc);
- *conjunctions* (and, or, if, because, but etc);
- *interrogative-indefinite-relative pronouns and adjectives* (who, what, which, whoever, whatever, whichever etc);
- *demonstrative adjectives and pronouns* (this, that, other, the same etc);
- *main adverbs* of place, time, manner etc (here, there, where, when, how, why etc);
- *pronouns and adjectives of quantity* (all, whole, many, some, few etc);
- *negation* (not, no, in- or un- as a prefix);
- *numerals* (one/first/once; two/second/twice; three/third etc);
- “*grammatical*” *verbs* like “to be”, “to have”, “can”, “must” etc;
- most *morphemes* in the large number of languages that have a more or less rich morphology (the ones which indicate *cases*, in languages that have cases; the *number* of nouns and, in many languages, of adjectives; *tenses, moods, forms, aspects* of the verb etc).

Besides the “grammatical” words, the vocabulary of a language contains other words that, like the former, do not seem to refer (or refer only) to something physical. The passage contains two of these words: “small” and “piece”. Other examples of words of this kind can be: “big”, “part”, “beginning”, “end”, “to get”, “to make”, “to look for”, “to find” etc.

It is easy to realise that the number of items in class 2 is quite limited (definitely much less than in class 1), but, *as a class*, they are used *in an extremely frequent way* (in the passage, the ratio between the words of class 1 and the words/morphemes of class 2 is about 1:4). If we choose samples of language at random, we can see that the words/morphemes of class 2 are, in a large majority of the cases, the main component of sentences and that they are *absolutely indispensable in order to speak*, that is, to construct *any* speech. Therefore, it is logical to consider them *fundamental*. All the words of a language are certainly useful

² The correct term is “appositions”, because various languages, unlike English, have *postpositions* rather than *prepositions*. In this article, where great efforts have been made to avoid using a technical language, we shall use the term “prepositions” even when the term “appositions” should be used.

(otherwise, they would not exist) and many words in class 1 can also be considered fundamental from a certain point of view. A word such as “water” is surely, from a certain point of view, fundamental. However it is possible to write *a whole book* without using the word “water”. Instead, one can easily realise that it is impossible to form *even the simplest sentence* without using some of the words/morphemes in class 2. Therefore, we can say that the words/morphemes in class 2 are the fundamental *structural component* of language, and then of linguistic thought (I use the expression “linguistic thought” because some authors stress the existence of kinds of thought that differ from the kind of thought that language is the expression of, the “internal” equivalent of language [see, for example, Weiskrantz 1988]). I maintain that *until we understand the nature of the meaning of these words/morphemes, we shall not be able to understand the deep nature and structure of language and linguistic thought*.

Well, what do these words or morphemes indicate? Let us consider a list of basic words (Table 1).

Table 1.

woman, man, animal, bird, dog, eye, nose, drink, eat, fly (verb), walk, sun, moon, water, stone, sky, fire, red, green, night, day, warm, cold, I, you, in, with, of, have, get, make, this, that, here, there, who, what, where, when, how, not, all, many, some, few, other, big, small, long, short, wide, narrow, thick, thin, near, far, right, left

Some people who are not familiar with linguistics could initially think that the meaning of words, that is, semantics in general, is not a problem. In fact, one can initially think that words are nothing else but signs that have been created to indicate *objects*. The very many words of a language that belong to class 1 (in Table 1, the first 23 words) can make us think so. This theory is undoubtedly correct to some extent. However, if we stop and think, we realise that things are not so simple. Words in the list such as “bird” and “animal” clearly show that in some cases we designate categories, not objects. Yet, if we think carefully, even more specific words such as “dog” designate categories. In fact, the word “dog” is unique, but there are many kinds of dogs. Even if we consider more uniform biological species than dogs, often not all the specimens of a species look exactly the same. Nevertheless we designate them with the same word. We can say that this applies to the majority of natural objects, and artificial ones as well. Cases where a word designates a single object or a class of identical objects are the exception, not the rule. Therefore, perception (and the designation that follows) is almost always a *categorisation*, not a sort of “photography” and memorisation of it. We can then say that what we designate is often not a single object, but a “category” or “concept” or “prototype”. However the problem does not end here. If we consider the words in Table 1 that seem to belong to class 2 (from “in” to the end), things get complicated. The meaning of some of these words, namely “big”, “small”, “long”, “short”, “wide”, “narrow”, “thick”, “thin”, “near”, “far” (in their literal meaning), “right” and “left”, may seem less problematic, because of their reference to space or time (even if this reference is not always present). But the meaning of the other words in the list, such as “to have”, “to get”, “to make”, “with”, “genitive”, “not”, is clearly problematic. First of all, not only do these words

not indicate physical objects, but neither do they indicate *relationships* amongst physical objects. In fact, we can say both “bottle *of* wine” and “stream *of* consciousness”, both “he *has* a moustache” and “*to have* an idea”, without changing the meaning of the preposition “of” in the first couple of examples, and of the verb “to have” in the second. In order to understand the difficulties that linguistics has encountered in defining such words, we can simply examine their definitions in dictionaries. Some of these definitions are clearly tautologies. For example, “not” is defined as “negation”, “all” is defined as “totality”. The definitions that send us from one word to another and then back again (for example, the verb “to look for” is defined by means of the verb “to find” and vice versa) are also tautological. Some of these words are said to have different meanings according to the context, and a synonym is provided for each meaning (for example, the synonyms that are provided for “to have” are “to possess, to own”, “to keep”, “to get, to obtain”, etc; the synonyms for “to get” are “to obtain”, “to purchase”, “to catch”, “to receive”, “to understand”, “to become”, “to arrive” etc; the synonyms for “to make” are “to create”, “to construct”, “to produce”, “to constitute” etc), but it is definitely much more convincing to think that the meanings of these more “specialised” verbs are *included* in the *much more general* meanings of the verbs “to have”, “to get” and “to make”. Dictionaries have long lists of relationships for words such as “with” and “of”, which are said to represent the many meanings of these prepositions (for the preposition “with”: company or union, means or instrument, manner, cause etc; for the preposition “of”: possession, association, belonging to a group, composition, containing, participation in an action as an agent or as a patient, origin, cause, purpose, quantity, quality, denomination, plenty or lack, topic, in respect to, fault, accusation and similar things, age etc). One could easily object by saying that it seems highly unlikely for words, which occur so frequently (the preposition “of” is the second most used word in English [Graffi & Scalise 2002 p 159]) and are so indispensable, to have so many meanings. These prepositions are more likely to have *only one, more general meaning* (which is why it is so difficult to determine), and the many relationships grammar speaks about *are included* in this more general meaning.

Another big problem in linguistics is defining fundamental grammar concepts such as “subject” and “object”. In linguistics, there are no satisfactory definitions of these concepts (i.e. definitions that always work) [Graffi & Scalise 2002]. Yet even primary school children learn what subject and object are without any difficulty through examples. Therefore, it is logical to think that *something fundamental is escaping us* here.

In linguistic research, a serious, wide and in-depth approach to Semantics such as the one by Wierzbicka [Wierzbicka 1972, 1989a,b, 1992; Goddard 2001, 2002; Goddard and Wierzbicka 1994, 2002] clearly shows how big a problem the semantics of the fundamental linguistic elements is and why. The approach (called Natural Semantic Metalanguage, NSM) is based on a reductive paraphrase (that is, breaking concepts/words down into combinations of simpler concepts/words).

This approach shows that most words in a language can be defined, yet there is *a core of fundamental, “atomic” meanings* (which Wierzbicka calls “semantic primitives”), which allow us to define any other meaning, but are *absolutely irreducible*, that is, *undefinable* by means of other words, as Wierzbicka explicitly states. The “semantic primitives” are believed to be present in all human languages. This assumption was tested extensively against a wide and extremely diversified range of languages. Table 2 shows the present list of the 60 or so “semantic primitives”. The words that seem to belong to class 2 are underlined. As we can see, they are the majority of the list.

Table 2. List of the semantic primitives
(2002; <http://www.une.edu.au/lcl/nsm/nsm.php> - model)

substantives: <i>I, you, someone, people,</i> <i>something/thing, body</i> determiners: <i>this, the same, other</i> quantifiers: <i>one, two, some, all, many/much</i> evaluators: <i>good, bad</i> descriptors: <i>big, small</i> intensifier: <i>very</i> mental predicates: <i>think, know, want, feel, see, hear</i> speech: <i>say, word, true</i> actions, events, movement, contact: <i>do, happen, move, touch</i>	existence and possession: <i>there is/exist, have</i> life and death: <i>live, die</i> time: <i>when/time, now, before, after, a long</i> <i>time, a short time, for some time,</i> <i>moment</i> space: <i>where/place, here, above, below; far,</i> <i>near; side, inside; touching</i> “logical” concepts: <i>not, maybe, can, because, if</i> augmentor: <i>very, more</i> taxonomy, partonomy: <i>kind of, part of</i> similarity: <i>like</i>
---	---

Therefore, Wierzbicka’s approach shows that in any language, and therefore *in language*, the core of the *most fundamental* meanings cannot be defined by using the words of the language itself (Arnauld, Descartes, Pascal and Leibniz had already maintained this theoretically [Goddard 1998]). As a result, the solution to the problem of the meaning of the words/morphemes that make up this fundamental component of language has to be searched for *outside* language itself, that is, in something other than language. These words/morphemes should be defined in terms of something more elementary.

Operational Semantics is a *completely new solution* to the problem of the meaning of the basic words/morphemes belonging to class 2. The fundamental thesis of OS is that *these words/morphemes designate sequences of mental operations* (the name “Operational Semantics” derives from this), *amongst which the ones of attention play a key role*. Therefore, we may say that *these words and morphemes are “tools to pilot attention”* [Marchetti 2003, 2006] *and other cognitive functions* of the listener. The reason why the meanings of such linguistic elements cannot be defined by means of other words is precisely because *they can only be defined in terms of such operations*.

Ceccato called these sequences of mental operations “mental categories” (because they have some analogies with the categories of Kant’s philosophy). OS has adopted this name as well. We must point out that the meaning OS gives to the term “category” is *completely different* from the meaning that cognitive psychology and linguistics give to the same term. Typically, cognitive psychology and linguistics use the term “category” to highlight the fact that, since many objects of the physical world share common features, but are not identical, we create *classes* (that is, *categories*) by means of a mental process of abstraction [Barsalou,

1999; Lakoff, 1987; Rosch, 1973, 1978]. On the contrary, OS calls “mental categories” the meanings of the words of class 2.

Ceccato called the mental operations that make up the mental categories *elemental mental operations*. Once again, we must point out that the use OS makes of the expression “elemental mental operations” differs completely from the use that cognitive sciences make of the same expression: while for OS the expression denotes only the elemental operations that make up mental categories, for cognitive sciences it has a wider meaning, denoting various kinds of operations that may be considered “elemental”, such as, for example, basic operations of perception. In this paper we shall therefore use, as much as possible, the more specific expression “elemental operations that make up mental categories”, or its acronym EOMC.

Therefore, defining the meaning of a word that designates a mental category means, according to OS, identifying the structure of that mental category, that is, the sequence of elemental mental operations that make it up. We call this task “analysis of a mental category”.

4. THE ELEMENTAL OR BASIC MENTAL OPERATIONS

Ceccato hypothesized that attention can only be in two states (attention waiting for something to focus on and attention focusing on something) and that the structure of mental categories is made up of the various possible combinations of a progressively increasing number (2, 3, 4 etc) of these two states. Since this hypothesis gave poor and controversial results in the analysis of mental categories, I believe it is completely wrong [Benedetti 2004]. Nevertheless, Ceccato also gave some other sketched descriptions of the structure of several mental categories. I used these descriptions as a starting point to identify the elemental mental operations that make up the mental categories. I proposed [Benedetti 2005b, 2006] a more complex set of EOMC, and consequently present new analyses of the fundamental mental categories. Most of the operations that are considered EOMC have been repeatedly described in cognitive psychology (as regards attention, see for example James, 1890; Jonides, 1983; La Berge, 1983, 1995; Pashler, 1998; Posner, 1980, 1994; Posner, Cohen, 1984; as to representation, see Braga-Illa, 1997, 2006; Denis, 1989; as to memory, see Baddeley, 2000; Baddeley and Hitch, 1974; Cowan 2001, 2005; Miller, 1956; Oberauer, 2002; Oberauer et al. 2000; in general, see Benjafield 1997, Reed 1992). *The new idea we are proposing is that by means of these operations we can account for the meaning of the words in class 2, hence for the nature and structure of linguistic thought* (this idea is Ceccato’s own).

The list of the EOMC I propose at present is the following:

- 1) *Operation of attentional focalization (AF)* – This operation has the fundamental property of producing the “selection”, or “highlighting”, of its object with respect to all the rest [James 1890]. Inside AF we can distinguish at least three sub-operations.
 - a) AF can widely *vary in extension (AFext)*: it may concern an object, or a part of it, or several objects.
 - b) The focus of attention can *move (AFmov)* from one object to another, or from a part of the field to which it is applied to another.
 - c) Moreover, AF can *last for variable*, though limited, *amounts of time (AFdur* [dur = duration]).

- d) The extension, movement and duration of attentional focalization can be estimated in quantitative terms (*AFext-estim*, *AFmov-estim* and *AFdur-estim*, respectively).
 - e) AF can vary in intensity (*AFint-var*), that is, we can pay more attention to one object instead of another.
- 2) *Presence keeping (PK)* – Let's consider Picture 1. In this picture, let's look at the bottle and say "bottle"; then, let's look at the glass and say "glass". Let's try to say, "there are a bottle and a glass". Obviously, the physical situation has not changed, but it is our mind that has done something different. In the first case, when we passed to the glass, the bottle was mentally left. In the second case, instead, we keep the bottle present while our attention passes to the glass. I call this fundamental operation "presence keeping".



Picture 1.

- The operation of presence keeping is surely strictly related to the well-known concept, developed by cognitive psychology, of "working (or active) memory", whether in the classic Baddeley-Hitch's model or in more recent models, such as Cowan's or Oberauer's models [Baddeley, Hitch 1974; Baddeley 2000; Cowan 2001, 2005; Oberauer, Süß, Schulze, Wilhelm, Wittmann 2000; Oberauer 2002]. The operation of presence keeping requires the interaction of a short-term memory having a limited capacity and attention (the interaction of a short-term memory and attention is especially highlighted in Cowan's and Oberauer's models).
- 3) *Operation of attentional discarding (AD)* – Considering Picture 1 once again, let's try to say "glass or bottle". In this case, we can easily sense that both objects are focused on by attention and kept present, but when our attention focuses on the bottle, we must *exclude*, *discard* the glass (this operation is different from simply stopping to focus our attention on an object in order to pass on to focus it on another one, because in our case we bear in mind the fact that we considered the object we are now discarding). I call this operation the operation of "attentional discarding".
 - 4) *Operation of representation (R)* – The operation of representation is the act of thinking about something that is not present at the moment. This is what we do when, for example, hearing a word, we pass to its meaning, which was previously memorised. Sometimes the formation of a mental image of the object follows the understanding of the meaning. In some cases, this operation is not simply a retrieval of something memorised, but has a clearly creative character, such as when we imagine or think up something that does not exist.

- 5) *Operation of comparison (C)* – Our mind performs comparisons very frequently. Every time we use typically relative words, which concern properties of an object (like “high/low”, “big/little”, “long/short”, “strong/weak”, “heavy/light” etc) or express a judgement (like “good/bad”, “normal/abnormal”, “legal/not legal” etc), we make comparisons. Obviously, when we perform this operation, we focus our attention on the objects compared and we bear them in mind. Even though comparison implies operations of attentional focalization and presence keeping, I believe that it has to be considered a separate function. This is why I call it “extra-attentional” operation.
- 6) *Operations of memory (MO)* – Memory surely plays a key role in our mental life: by means of it, we fix and recall both brief and long-term memories continuously. Apart from all of this, I think that memory operations are part of the structure of some mental categories [Benedetti, 2005b, 2006]. Therefore, I list memory operations amongst the basic mental operations that make up mental categories. Also these memory operations are distinct from the ones of attention.

5. EXAMPLES OF ANALYSIS OF FUNDAMENTAL MENTAL CATEGORIES

Naturally, the mental categories that we must concentrate on are the “primitive” ones, that is, those that cannot be defined by means of other words. Wierzbicka’s method seems to identify them precisely. Her work also shows that the “semantic primitives”, which have been identified using this method, are probably universal. Therefore, we shall use this list as a primary source. Even if Wierzbicka’s work seems to be extremely serious and rigorous, I suggest using another list to provide confirmation to the reader. I have intentionally chosen a list that was created in a completely independent way, in a field other than semantics and for a completely different purpose: the Swadesh list. The Swadesh list contains about 200 words that are considered fundamental, and is used in so-called “glottochronology” to determine the degree of “kindred” of languages and the approximate date of their separation. From our point of view, the criticisms that have been made about glottochronology do not matter: what matters is that the Swadesh list is a set of words that are fundamental and present in all (or almost all) languages. This is probably true. Table 3 shows the words of the Swadesh list that at first sight seem to be mental categories³.

³ The complete list is: I, you (singular), he, we, you (plural), they, this, that, here, there, who, what, where, when, how, not, all, many, some, few, other, one, two, three, four, five, big, long, wide, thick, heavy, small, short, narrow, thin, woman, man (adult male), man (human being), child, wife, husband, mother, father, animal, fish, bird, dog, louse, snake, worm, tree, forest, stick, fruit, seed, leaf, root, bark, flower, grass, rope, skin, meat, blood, bone, fat (n.), egg, horn, tail, feather, hair, head, ear, eye, nose, mouth, tooth, tongue, fingernail, foot, leg, knee, hand, wing, belly, guts, neck, back, breast, heart, liver, drink, eat, bite, suck, spit, vomit, blow, breathe, laugh, see, hear, know, think, smell, fear, sleep, live, die, kill, fight, hunt, hit, cut, split, stab, scratch, dig, swim, fly (v.), walk, come, lie, sit, stand, turn, fall, give, hold, squeeze, rub, wash, wipe, pull, push, throw, tie, sew, count, say, sing, play, float, flow, freeze, swell, sun, moon, star, water, rain, river, lake, sea, salt, stone, sand, dust, earth, cloud, fog, sky, wind, snow, ice, smoke, fire, ashes, burn, road, mountain, red, green, yellow, white, black, night, day, year, warm, cold, full, new, old, good, bad, rotten, dirty, straight, round, sharp, dull, smooth, wet, dry, correct, near, far, right, left, at, in, with, and, if, because, name.

Table 3.

this, that, here, there, who, what, where, when, how, not, all, many, some, few, other, count, one, two, three, four, five, big, small, long, short, wide, narrow, thick, thin, give, hold, correct, near, far, right, left, straight, round, new, old, at, in, with, and, if, because

As we can see, most of these are the same as the ones included in the “semantic primitives” of NSM (or are very similar: for example, “in” is very similar to “inside”, “how” is similar to “like” (some languages use the same word), “who/what” is not so different from “someone/something/thing”). Therefore, a list that has been created independently and for a completely different purpose substantially confirms Wierzbicka’s list. The fact that very few words are not common to the two lists does not matter to us here. In fact, we are not interested in identifying *only* the meanings of the “primitives”. We are interested in having a list of these meanings that is presumably complete, in order to see if our method of analysis works for them. But we can also consider some more meanings, if they seem very important (which is what we shall actually do: for example, the verb “to have to”, which is easily paraphrasable with “cannot not”, is not included in Wierzbicka’s list, but, since it seems as important as “can”, we shall consider it).

This section deals only with a part of the mental categories that are considered fundamental, in order to use them as examples of analyses. The others will be considered further on, either because it is more appropriate to introduce certain concepts, which are needed to understand the analyses, in later sections, or for other reasons.

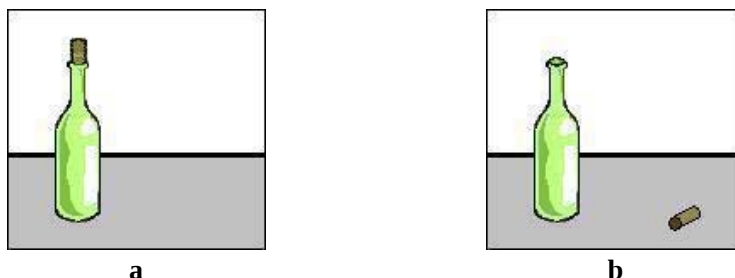
Only the results of the analyses are introduced here. The methodologies that have been used and the way in which they have been developed cannot be discussed in this short introductory chapter.

Noteworthy here is the fact that OS considers the problem of the meaning of the linguistic elements belonging to class 2 *from as general and “deep” a point of view as possible*. Wierzbicka’s approach clearly shows that there are some meanings that cannot be defined by means of other words and are probably present in all languages, i.e. they are universal. Such “semantic primitives” are obviously expressed by linguistic elements (words or morphemes). In each single language, these linguistic elements can present some particularities, above all of use (for example, in the same situation a certain language can use one word/morpheme, while another languages may use another), but also of meaning (for example, in one language a linguistic element can have an additional meaning that it does not have in another language, there can be various words that express the same fundamental meaning with different shades of meaning, etc). *OS does not deal with these linguistic particularities, but only the aforesaid presumably universal semantic primitives*. OS tries to account for the latter, without using, as a program, the concept of polysemy (which, as we stated, clashes with the uniqueness of the corresponding linguistic elements) and using the hypothesis that the “semantic primitives” must be something simple (since the corresponding words are amongst the first that little children understand and use).

After these preliminary remarks, we can provide some examples of the analyses.

The preposition *with* means that we focus our attention (AF) on something, *A*, then, keeping it present (PK), our attention also extends (AFext) to something else, *B*, because *B* is in such a relationship with *A* that our attention tends to include *A* and *B* in a single

focalization⁴. For example, we say “bottle with cork” if the cork is in the neck of the bottle (Picture 2a), while we do not use this expression if the cork is far from the bottle (Picture 2b).



Picture 2.

Generally, the two things that the preposition links cannot be inverted because one of them is (or is considered) the main one (“bottle with cork”, not “cork with bottle”). Nevertheless, when the two things are equally important, they can be inverted (“I saw John with Bob/Bob with John”), and which will be the first depends on which we are more interested in.

A noteworthy fact is that this analysis clearly explains that in many languages this preposition is used to express both the relationship of company or union between two things and the relationship of means or instrument between an activity and an object. Whether we say, for example, “cup with handle” or “to write with a pen”, what appears to our attention are two things that are in such a relationship that our attention, when focused on A, tends to include B in the same focalization as well. In fact, the handle is joined to the cup and therefore as long as we look at the cup we also see the handle; and as long as we watch the action of writing we see the pen (Picture 3).



cup with handle



to write with a pen

Picture 3.

The analysis also clearly explains that the preposition “with” can be used when relationships such as object-its part (“book with a red cover”), opposition (“to fight with”), manner (“with ease”), simultaneousness (“swallows migrate with the cold season”), cause (“to shiver with fear”), concern (“no concern with”) are involved, and in comparisons (“to compare with”). In all these cases the attention, while focusing on something, is also extended to something else (from the act of fighting to the enemy, from an activity to the way it is performed, from an event to another one that happens at the same time, etc).

⁴ This analysis is my (substantial, from a certain point of view) modification of the original Ceccato’s analysis (which is: “two things are focused together by attention and then they are divided by it”).

Therefore, the preposition *does not designate the aforesaid relationships*, that is, they are not *its meanings* (which would be too many). The preposition designates a *much more general* relationship, i.e. *A* is in such a relationship with *B* that attention, when focused on *A*, is also led to “embrace” *B*. This very general relationship can include various more specific relationships (manner, simultaneousness, cause, etc), which depend on the two related things, but the meaning of the preposition is only the first relationship, *not the second ones*. Therefore, *there is only one meaning for the preposition*, in agreement with the fact that there is only one corresponding word.

As we shall see, this is also true, at least in principle, for the other prepositions or cases that linguistics generally considers as polysemous. This clearly shows how much OS differs from previous theories in semantics.

I have introduced the analysis of the preposition “with” first, because it illustrates a fundamental general concept of OS very well (this is indeed valid for several other words/morphemes, as we shall see). This concept is that *the meaning of these words/morphemes can be found only at the top level of abstractness*, that is, at the level of the operations of attention and other basic cognitive functions, *not at more particular levels* such as the spatial, temporal, causal, instrumental etc relationships.

The category of *negation* (“not”, “no”, “in-” or “un-” as a prefix) indicates the discarding (AD) of the representation (R) of a meaning (the analysis is my own). If, for example, we say, “John’s car is not red”, we mean that the representation of the meaning “red”, concerning John’s car (a representation that was prompted by something previous, such as for example the question: “Does John have a red car?”) is discarded.

The categories *who*, *what* and *which* indicate the fundamental operation of attention of selecting an unspecified item A_x from a group of two or more items ($A_1, A_2, A_3, \dots$), which are considered equal (C), and kept present (PK). The only difference between “who” and “what” is the kind of item: human beings in the case of the pronoun “who”, anything that is not a human being in the case of the pronoun “what” (“which” is the derived adjective). If, for example, there are some books (Picture 4), and we ask someone “Which book do you want?”, we will realize that we are keeping in mind the group of books, while our attention is waiting to focus on one of them.

Focusing our attention on an element of a group, while discarding the others, is obviously an operation of fundamental importance. In fact, linguistic research has shown that the two pronouns “who” and “what” are among the first in the list of the most stable words in the linguistic evolution of the languages of the world [Dolgopolsky, in Lehmann, 1992, p 217 It. ed.].

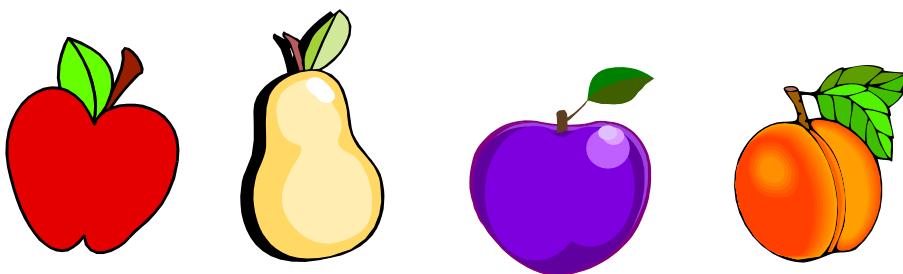
The category “how many” (for the singular form, “how much”, see further on) is produced by means of the operation of *counting*, that is, by means of a series of operations of focalization of attention (AF), one after the other, on each item of a group of items considered equal (C), bearing in mind (PK) the preceding items each time we add a new one. Each subsequent repetition is called by a different name (these are the *single numbers*: “one”, “two”, “three” etc). The word *number* indicates indistinctly one of these repetitions without specifying which one, while the word *how many* indicates that attention must be focused on the final result of counting. The category of *plural* indicates that we have simply carried out subsequent attentional focalizations on things considered equal, but without associating a

conventional name of a progressive series (that is, a number) to each of them⁵. For example, if, when looking at a scene with an apple, a pear, a plum and a peach (Picture 5), we say “there are four fruits”, this happens because, first, we have considered the apple, the pear, the plum and the peach as items that are equal (that is, “fruits”); second, we have focused our attention on one of them associating a conventional name (“one”) to it; third, while bearing this in mind, we have focused our attention on a new item associating another conventional name (“two”) to it; and so on. If instead we say “there are some fruits”, we have carried out the same operations, but without the association of a progressive series of conventional names.

Besides the definition of “number” (that is, the fundamental entity of Mathematics), I would like to mention the definition of a fundamental entity of Geometry, that is, “point”. Ever since the origin of Geometry, point has been considered one of the so-called “*primitive concepts*” (Euclid), that is, the fundamental concepts that we acknowledge *without a definition*. According to OS, the *point* designates an attentional focalization on a spatial “map” (see further on), focalization which is so restricted that attention cannot move inside it anymore⁶. If we wish to illustrate this operation with a scheme, we may use a picture like Picture 6, where we suppose that, as often happens, there is a restriction in the extension of the attentional focalization, as happens when we pass from any object (in the picture, it is symbolised by the circle) to a single point of it.



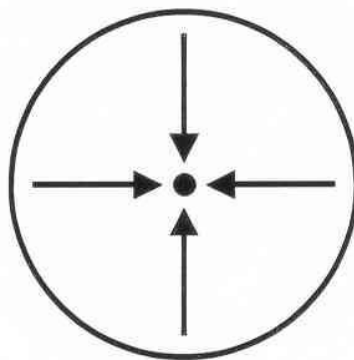
Picture 4.



Picture 5.

⁵ The analysis of the category of “plural” is my own. The other analyses of this group are developments or modifications or explanations of analyses sketched by Ceccato.

⁶ This analysis is completely my own, that of Ceccato being completely different. The fact that Ceccato did not sense that the movements of attention are fundamental attentional operations makes his analyses of the mental categories that have something to do with space some of the least convincing of his work, in my opinion (it is not by chance that they also are very few).



Picture 6.

Now, let's consider the meanings "other/else" and "the same". There are a lot of objects of which many specimens exist, which are thus designated with the same word. For example, the word "dog" indicates each specimen of the class of "dogs". If, in a speech, after having found one of these words we find it once again, we remember that the word has been already used, so we have to know whether the latter word refers to the aforementioned specimen (let's call it A_1 of class A) or not. The mental category *the same* indicates that we have to focus our attention again on A_1 retrieved from memory, while the category *other/else* indicates that we have to discard A_1 retrieved from memory and represent a new specimen of class A , let's call it A_2 (therefore, these categories are examples of categories with memory operations in their structure). These analyses agree perfectly with linguistic data. The word that expresses the meaning "other/else" is rather stable during linguistic evolution, while there is not such a stable word that expresses the meaning "the same" (this is the reason why Swadesh list, which is a list of universally widespread fundamental words, includes the word "other/else" only, while Wierzbicka's list, which is a list of fundamental meanings, includes both meanings). In the Indo-European linguistic family, for example, the root ALI, "other/else", can be clearly reconstructed starting from its derivatives that are largely widespread across the languages of the family, while a root that means "the same" cannot. The stability of the word that means "other" and the absence of a stable word for the meaning "the same" is due to the fact that the former is necessary, while the latter is useful, but not strictly necessary. In fact, if we have to discard A_1 retrieved from memory and represent A_2 , we need a specific word, but if we just have to focus our attention again on A_1 retrieved from memory, we can simply repeat the word leaving the thing understood, or use a demonstrative adjective/pronoun or the definite article (if the language has the latter).

The meanings of the two verbs "to have" and "to get" are so general that dictionaries usually try to capture them by defining each entry with a long list of verbs, as we have seen. However, these lists are nothing else but collections of more "specialised" verbs, whose meanings are included in the more general meanings of "to have" and "to get". The meanings of "to have" and "to get" are so general because both these verbs designate the same relationship as the one designated by the preposition "with"⁷ (two distinct things, A and B , are in such a relationship that our attention, when focusing on A , tends to include B in the same

⁷ This basic idea, and the difference between "to have" and "to get" described below, are Ceccato's own; as regards the analysis of the proposition "with", see note 4.

focalization as well). The difference with the preposition “with” is that, in the case of these two verbs, as in all verbs, we see the situation from the temporal point of view, which entails that we focus our attention in a continue way or repeatedly on the *same* situation (see further on). In the case of the verb *to have*, the result is something static. For example, “that man has a moustache” means that when we focus our attention on his face we also see a moustache and this remains constant throughout time. On the contrary, in the case of the verb *to get*, the result is something dynamic. For example, “to get the pen” means that our hand comes in such a relationship with the pen that, if we look at the hand, we also see the pen (the pen is *in* the hand), while before there was not such a relationship⁸.

I use Picture 7 to show the analyses of the conjunctions “and” and “or” (these analyses are substantially Ceccato’s own). In the case of the conjunction *and* (“an apple *and* a pear”), we focus our attention (AF) on something (say A; the apple, in our example) and we keep it present (PK) while focusing our attention (AF) on something else, B (the pear). In this way B is “tied” to A, but remains separated from it because attentional focalization stops during the passage from A to B, that is, we perform two distinct operations of attentional focalization. In the case of the conjunction *or* (“an apple *or* a pear”), firstly we focus our attention (AF) on an object A (the apple, in our example) and then we discard (AD) it in order to focus our attention (AF) on another one, B (the pear). Therefore, A is excluded when B is taken into consideration: an alternative between the two objects is thus created.



Picture 7.

A very important group of mental categories is the one designated by the words and morphemes frequently (some of them exclusively) related with space or time (for example: “place”, “where”, “here”, “there”, “high”, “short”, “wide”, “narrow”, “left”, “right”, “now”, “before”, “after”, “during”, “when” etc). In order to analyse the meaning of these linguistic elements we have to introduce some concepts.

In my opinion, the attentional operations and the other EOMC can be applied not only to objects, but also to what I call “maps”. I call “*map*” an ordered mental representation of an ordered set of elements or of an ordered *continuum* (since here I use the word “map” in a new meaning, I shall always put it between quotation marks). Examples of “maps” are the representation of the series of numbers, of the words of a speech, of the items of a list, etc. Nevertheless, the main “maps” are the spatial “map” and the temporal “map”, that is, our mental representations of space and time.

Let’s consider the *temporal* “*map*” first. As everyone can easily sense, when we have focused our attention on an object, we can continue keeping it on that object. If the situation

⁸ The restricted space of an article do not allow us to show other examples in order to verify these two analyses and the other analyses that I have proposed. Nevertheless, the reader can easily verify them himself or herself by

is static, we can keep our attention on the same object for rather brief periods, a few seconds. Think, for example, about when we look at a red traffic light waiting for the green one: after a very few seconds of gazing at the red disk, our sight is inevitably pushed, even against our will, to look away from it at least for a moment. In the case of dynamic situations (for example, when our eyes track a moving object), we can keep our attention focused on the same object for longer periods. Nevertheless, we have to note that even in situations of this kind rarely do we keep our attention exactly on the same object. That is, attention is extremely “mobile”, that is, it tends to move continuously in the attentional field (the reason for this is easily understandable: only with a continuous exploration of the attentional field it is possible to perceive all the stimuli that could be important for the subject). Anyway, even if we can keep our attention focused on the same object for limited periods only, it is possible, once we have left the object, to focus it on again. This is what we do for example in the aforesaid case of waiting for the traffic light to become green, when the waiting is rather long: we keep our attention on the red disk for some seconds, then we divert it for a moment, then we gaze again at the red disk, etc, till it goes out and the green disk appears. This kind of operating can cover even long or very long periods. In fact, we can focus our attention again on the same object even after many years (for example, when we knew a man when he was a boy and we meet him again when he is an adult). Whatever the distance of time between the two (or more) attentional focalizations, all that is necessary is that their results are remembered and that there is some way of ascertaining without any doubt that the object of the attentional focalizations that follow the first one is always the same as that of the first focalization, even if the object has not been continuously followed. Furthermore, we usually integrate what we perceived during the phases of the attentional focalization, representing, that is, imagining, what happened during the phases when our attention was elsewhere directed, so as to build a *continuum* where the object has a stable existence (for example, when we are waiting in front of a traffic light, we assume that the red disk still exists also when we divert our attention away from it; as in the case of the man met after many years, we assume that he gradually changed from a boy into an adult ; etc). As we can see, this way of operating is a rather complex one, where there can be several operations of attentional focalization, operations of memory and of representation. Because of this, I call it temporal “operational scheme” (TOS).

When we perform this fundamental operational modality, we use a **verb**. This fact may be not immediately evident. This depends on the fact that we *already know* the meanings of the various verbs and this may make us think that these meanings can be understood in an instantaneous way, without necessarily following the situation during time. But imagine you want to teach the meaning of a verb, for example “to burn”, to a very little child who does not know it: to do this, there is no other way but to make the child keep his or her attention on something that is burning, for example some wood, and see it changing into something else (the ashes) during time, while producing heat and fire. The fact that the use of a verb implies a non-instantaneous application of attention is clearly demonstrated when, in order to choose the verb that describes a given situation correctly, a prolonged observation is necessary. For example, when watching a ship on the horizon, it would be impossible to say “that ship on the horizon is still” or “that ship on the horizon is moving” if the observation were instantaneous.

The result of TOS is a temporal representation or “map” relevant to a process (or state). By capturing the relationships among the various phases of many processes (or states) and by using some cyclic processes (the alternation of day and night, the lunar phases, the seasons etc) as a privileged reference, we build a temporal “super-map” where all other temporal “maps” are integrated, that is, the general representation of time (the complexity of such a process is evident and accounts for the fact that children come to possess a representation of this kind late).

As we all know, the verb is commonly considered to be the fundamental component of sentences. This is because the verb designates that the temporal dimension, which is a truly fundamental dimension, has been considered. In fact, using substantives *alone* (for example, “dog”, “tree”, “stone”) has little sense. It is instead fundamental to say what happens to things of this kind *over time*, that is, how they are evolving, either in a static or dynamic way⁹.

A **spatial “map”** is what allows us to consider an object or an environment from the spatial point of view, that is, in its extension. We can become aware of the activation of a representation of this kind if we make the two following simple experiments:

- 1) considering any physical object (for example, this page) in two different ways:
 - a) first, we simply recognise it (in this case, only its distinctive features, that is, its whiteness, its rectangular shape, etc will be evident);
 - b) then, we consider some positions on it (for example, the centre, the upper half, etc);
- 2) considering a part of the environment (for example, the room where we are) in two different ways:
 - a) first, once again we simply recognise it (also in this case, only its distinctive features will be evident);
 - b) then, we consider it as a “place” (in the latter case, the room will become a part of a wider spatial representation that includes it, for example the one of the house).

As regards the neurophysiological basis of the “maps”, maybe ordered sets of neurons are involved (structures of this kind, where single cells fire according to the position of the animal in the environment have been shown; generally speaking, wide areas of the cerebral cortex, which are distinct from the ones involved in the recognition of the objects, seem specialised in the visual spatial representation of the environment and in the localization of an object inside it [Kandel, Schwartz, Jessel, 2000]).

Just like the temporal “maps”, the very many spatial “maps” that we build and memorise during our life are integrated in a “super-map”, which is our general representation of space.

However we build our spatial and temporal representations, we clearly have the ability to do this. When a “map” is activated, attention can focus on it, selecting a more or less large part of it, moving around it, etc. In other words, we can perform the attentional operations (and the other operations) that are the elemental mental operations (EOMC) on the “map”. If the same operations that are at the basis of the mental categories “who/what/which” are

⁹ For an in-depth discussion of the psychological sensation of time, starting from the presuppositions of OS, see Marchetti 2009. The basic thesis of this article is that such a sensation is a subjective construction based on the

performed on a spatial “map”, that is, if we first focus our attention on a “map”, and we keep the “map” in mind while we focus the attention on a part (say *A*) of it, we obtain the mental category **place**, or **where** as an interrogative or relative adverb (for an analysis of the categories “interrogative” and “relative”, see further on). If we perform the same operations on a temporal “map”, we obtain the mental category **moment/time** (“time” in the sense of “portion of time”), or **when** as an interrogative or relative adverb).

Once the concept of “map” and performance of EOMC on it has been introduced, identifying the structures of the other mental categories related with space and time is very simple. We shall mention them for the sake of completeness only.

Spatial “maps” are uniform, that is, there is no privileged position or direction. Therefore, setting reference points and directions on them is very useful. The vertical direction (the direction of the force of gravity and the upright position) and the horizontal direction are often chosen as a reference of course. Using attention to select one of the two parts of a spatial “map” that has been divided either vertically or horizontally obviously makes up the two pairs of categories **right/left** and **high/low** (**up/down** as adverbs).

The quantitative estimate of attentional movement (AFmov-estim) is obviously the basis of the categories **near** and **far**. The choice of the speaker’s position on the “map” (and, in some languages, of the listener too) as a reference for this estimate is naturally the basis of the demonstrative adjectives/pronouns (**this**, **that**, and others in other languages) and various adverbs of place (**here**, **there** etc).

Typically relative terms such as **high/low** (as adjectives), **large/narrow**, **long/short** and **thick/thin** are obviously based on an operation of comparison (C), which concerns the extension of the one-dimensional attentional movement from one extremity¹⁰ of an object to the other extremity, along a reference direction that is chosen according to the object’s position in space or to the relationships among its three dimensions¹¹. If the two-dimensional (or three-dimensional) relative extension of attentional focalization (AFext-estim) is considered, we have the categories **big/small** (in the literal and fundamental sense of this pair of words of course, and not in the figurative sense, which also exists for some of the other pairs). Linear attentional movement can be of two fundamental kinds, with or without variation in direction (categories **round** and **straight**, respectively).

Unlike spatial “maps”, the temporal “map” has only one direction. On this “map” there is a privileged position, the one in which the linguistic communication takes place (the **present/now**, as a substantive and adverb, respectively), which divides the “map” into two

effort made by the organ of attention in focusing, in a continuous and incremental way, on a given object or event.

¹⁰ Naturally, the category **extremity** designates the selection of the point or part of an object that attention, moving in a linear way, meets before meeting something other than the object itself. If we choose one of the two possible directions of this movement as a reference, we have the category **end**. Obviously, in the category **beginning** the attention starts before the object and meets it after.

¹¹ In the case of the “**high/low**” pair, the reference direction is obviously the vertical one. We can also take the longest direction as a reference (“**long/short**” pair). The “**wide/narrow**” pair designates the extension of the dimension that comes second after length as to extension. Generally, we take the longest dimension as a reference: a) when the object has a dimension that is particularly longer than the others and this dimension is *not*, always or preferentially, vertically oriented (for example, a pencil); b) the object does not have a fixed position in space (for example, a pill box). If the object has a fixed position in space and generally we stand in front of it (for example, a bookcase) the horizontal dimension is generally referred to as “width”, even if it is the longest dimension. When the third dimension is particularly shorter than the other two the two terms “**thick/thin**” are used.

parts that are clearly identified by its unique direction, the **past** and the **future** (obviously, these three possibilities are also expressed by the **tenses of the verb**). The three possible positions of a given attentional focalization on the temporal “map” (that is, a moment) with respect to another are the three categories **before**, **after** and **during**. Naturally, the same operations that were said to make up the meanings of the “near/far” and “long/short” pairs are possible. Therefore, many languages designate them by means of the same words, both when they are applied to space and time.

Several of the words that we have just considered are also used not in relationship to space and time (“a *long* list”, “the subject must be put *before* the verb”, “*this* is the problem” etc). Of course, this is because, as stated, *any* ordered set of elements or ordered *continuum* (the series of numbers, the words of a speech, the items of a list etc) can be mirrored in a “map”, whereon the operations that are the meanings of these words can be performed.

6. THE CORRELATIONAL THEORY OF THOUGHT

Now that we have introduced some analyses of mental categories, we can explain how, according to OS, mental categories allow us to produce linguistic thought. Let’s consider the following words: “apple”, “pear”, “red”, “and”, “or”, “with”. Let’s try to represent each of the meanings of these words in an isolated way. This is easy for the first three words, while for the other three we have a clear sense of “incompleteness”. We sense very well that the last three words require something that precedes them and something else that follows them. In other words, their function is to “tie” two other elements to each other. According to OS, linguistic thought is made up of two fundamental kinds of elements:

- 1) correlators
- 2) correlata

Correlators are the elements that have the specific function of tying the other elements of thought. They are the mental categories designated by prepositions, conjunctions and some of the so-called cases (genitive, dative, etc), in languages that have cases (in languages that have no cases their meaning is expressed by means of prepositions). *Correlata* are the elements that are “tied” by a correlator. According to OS, even though the meanings of isolated words (such as “apple”) are a kind of thought, there is actual linguistic thought only when we “tie” or “correlate” more than one meaning to each other, that is, when we say, for example, “apple and pear”, “red apple”, etc. The two correlata that are tied by a correlator are called “first correlatum” and “second correlatum”, respectively, according to the temporal order in which attention focuses on them. We call the whole structure thus formed *correlation* or *correlational triad* and we represent it graphically in the following way:

correlator	
first correlatum	second correlatum

In the case of the example “pear and apple”, we shall have this correlation:

and	
pear	apple

Besides prepositions, conjunctions and some cases (in languages that have cases), there is another correlator, which is extremely important. Its structure is the same as for the conjunction “and” (attention focuses on *A* and *A* is borne in mind while attention focuses on *B*), but in this case *A* and *B* do not remain separate, but they “combine” together because the attentional focalization does not stop in the passage from *A* to *B* because *A* and *B* are in some way complementary. For example, *A* is an object that can exist on its own and *B* a possible feature of it (correlation substantive-adjective); or *B* is what may happen to *A* in time (correlation subject-verb); or *A* is an activity and *B* something the activity can be performed on (correlation verb-object); etc. We call this correlator *presence keeping* and we represent it graphically by means of a horizontal bar:

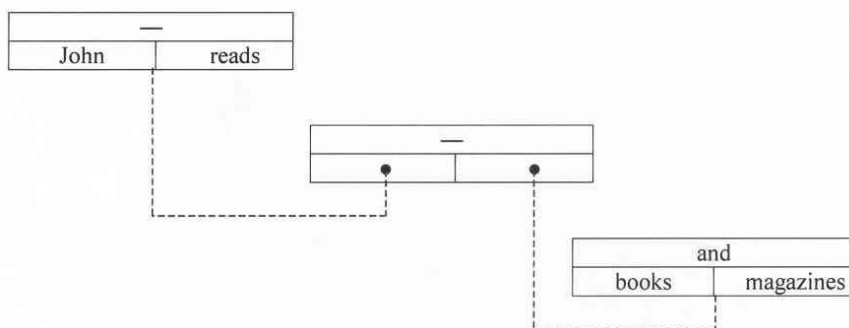
—	
green	leaf

—	
John	runs

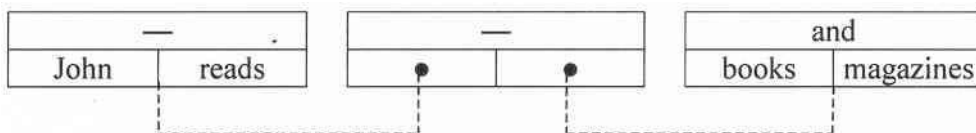
—	
reading	books

Since this correlator is, as we can easily understand, the most used of correlators, it is convenient not to express it with a word and to indicate its presence either by simply putting the two words that it correlates one after the other (when this is possible) or using marks of the words (English has very few marks of this kind, but many languages have several of them: for instance, in the Italian sentence “bottiglia di vino nuova”, which means “new bottle of wine”, the two “a” that are underlined are marks of the feminine genus, which indicate that the adjective *nuova*, “new”, has to be related to *bottiglia*, “bottle”, not to *vino*, “wine”). Because of this, this correlator has also been called *implicit correlator*. Nevertheless, it is really implicit only when no linguistic element (whether word order or word marks) expresses it, that is, only when we can understand which words it links only by the general sense of the sentence. For example, in the two expressions “empty whisky bottle” and “Scotch whisky bottle” only the sense of the expression tells us which noun the two adjectives “empty” and “Scotch” refer to.

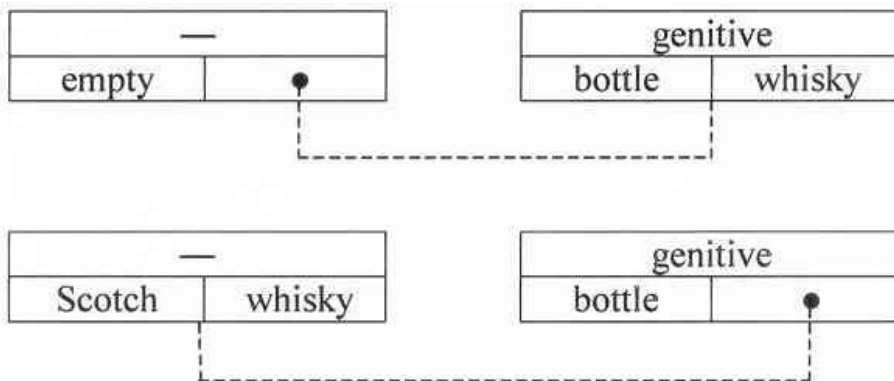
According to OS, correlation is the basic unit of thought. Thought is, in fact, a “network” formed by correlations (*correlational network*) in which a correlation acts as a correlatum of another correlation. Therefore, the sentence “John reads books and magazines”, for instance, has the following structure of thought:



(the dotted line that starts from the line that separates the two lower boxes of a correlation and that ends with the symbol “•” placed in one of the two lower boxes of another correlation indicates that the first correlation is one of the correlata of the second correlation). The graphical representation that we have used somehow resembles a network, so we use the expression “correlational network”. In order to use less space, we shall nevertheless use a graphical representation where the correlational triads are put on the same line, in this way:

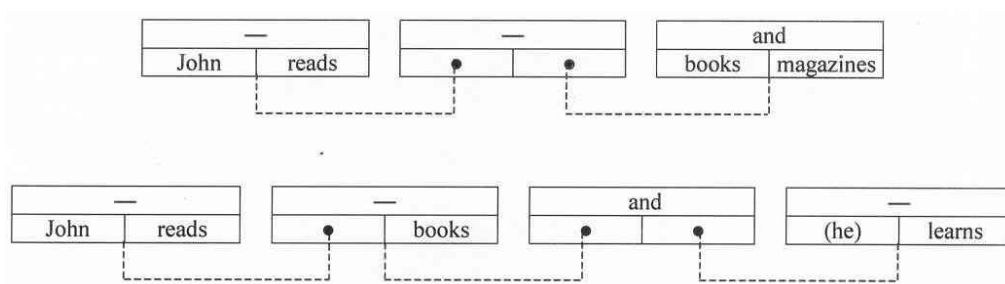


However, irrespective of the graphic representation, *it must be very clear that the structure of thought is not a simple linear structure where the elements are added one after the other*. The elements (that is, the meanings) that make up thought are surely loaded one after the other in working memory, and the previous elements are kept present while the next ones are added. However, what is formed is a precise *non-linear* structure, which can be different even when the words are spoken in the same order. For example, the two aforesaid sentences (“empty whisky bottle” and “Scotch whisky bottle”) are, from a certain point of view, identical (that is, they are made up of a first word, which, albeit different, is in both cases an adjective, plus two identical words in the same order), but the two corresponding correlational networks are different:



(in the two triads where the correlator is the genitive the order of the two correlata is inverted in comparison with speech order because English can use the inversion of the two correlata to express the meaning of the genitive; this would not have happened if the genitive had been expressed with the preposition “of”: see the analysis of the genitive further on).

Another example, which perhaps better explains the concept of network structure, is the sentence “John reads books and learns” vs the aforesaid sentence “John reads books and magazines”. Although the words are the same (except for the last one) and in the same order, the two structures of thought are very different, as we can see:



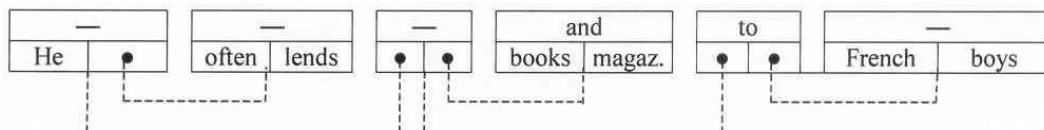
While thought has a *network* structure, language *necessarily* has a *linear* structure, because we must pronounce sounds one after the other, otherwise they would overlap and become unrecognisable. This is a problem, because a linear structure tends to be simpler and contain less information than a non-linear structure and, in the phase of language comprehension, we must pass from the former to the latter in an unequivocal way. There are three ways to solve this problem.

1. The first is to use, besides word order, marks for the words, i.e. slight modifications that add information about how words are related to each other in the structure of thought. This is done by languages that have a rich morphology, with many concordances (between noun and adjective in number, gender and case; between verb and subject as to person and, possibly, the gender of the person too; etc). We have seen an example of two Italian expressions ("bottiglia di vino nuova" vs "bottiglia di vino nuovo"), where the meanings are the same and in the same order, but the gender mark of the last word unequivocally indicates which of the two possible correlational networks is involved. This way of expressing the structure of thought makes a language more difficult to speak and learn, but has the advantage of making the reconstruction of the structure of thought, starting from speech, more sure and with less ambiguities.
2. The second is to use word order only. This sometimes requires a word to be repeated and/or more words to be used. For example, the French sentence "J'ai parlé avec Jean et Marie, l'anglais de laquelle est très bon" cannot be literally translated into English ("I talked with John and Mary, whose English is very good") because it would be ambiguous, since the English relative pronoun "whose" is the same for the singular and the plural and can refer to Mary or both persons. Therefore, the English must read, "I talked with John and Mary. Mary's English is very good". This way of expressing the structure of thought tends to be less effective than the former in making it explicit in detail.
3. The third is the knowledge of the listener. We have seen the example of the two expressions "empty whisky bottle" and "Scotch whisky bottle", where a general knowledge is sufficient. Sometimes a specialised knowledge is needed, such as in the expression "slow neutrons and electrons" (the correlational networks are different if the adjective refers to both particles or to neutrons only), or the necessary information is provided in the context, such as in the sentence "The boy hit the man with an umbrella", if preceded by some reference to a man who has an umbrella.

The theory of the structure of thought that has just been introduced is called *correlational theory of thought*. Below is the correlational network of thought that corresponds to a more complex sentence than those above:

He often lends books and magazines to French boys

which, from a certain point of view, can be considered a typical sentence (there is a subject, a verb, an adverb, a direct object, an indirect object, a conjunction and a preposition).



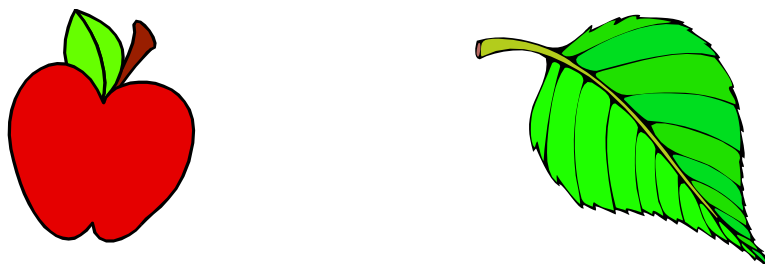
Also this example shows, even more clearly, that the structure of thought is more complex than the simple sequence of the words that express it.

Obviously, the correlational theory of thought is also a linguistic theory, but *deeply different from all other linguistic theories* because: a) it is above all a theory about the nature and structure of thought; b) it makes a clear-cut distinction between correlators and correlata; c) it considers linguistic thought a non-linear “network”, based on units necessarily composed of three elements, that is, one element that ties and two elements that are tied (even if sometimes the former is not expressed).

In my description of mental categories and thought, their procedural and architectural character is implicit. When mental categories are formed, a working memory is necessary to keep the result of the previous mental operation present while the following operation is carried out. Furthermore, a procedural memory is also necessary to carry out these sequences of operations starting from the linguistic input. When the correlational network of thought is formed, i.e. when mental categories of relationship (correlators) link correlata to each other, a working memory and, when we understand language, a procedural memory, are still necessary. Theoretically, the process of production of the correlational network can go on without limits. Practically, its limit is exactly the capacity of working memory. This corresponds to the well-known fact that sentences have a limited length (even if they can be very long) and are separated by full stops in writing and by pauses in speech. A **full stop** and the corresponding pause exactly indicate that working memory has stopped being loaded. What has been present in it up to that moment has to be in some way stored in a short-term memory. An item or a part of a correlational network or even a whole correlational network is often taken from short-term memory and loaded again in working memory in order to begin a new correlational network. This function, which we may call *recall function*, is very important, because it allows us to build even very complex thoughts. It is mainly carried out by pronouns. In the following two examples, the pronoun and the preceding part of the correlational network that it recalls are underlined:

- a) “*This morning I saw Bob. But he didn’t see me.*”;
- b) “*This morning I saw the German boy I knew at the seaside last summer. He told me...*”.

Given the level of complexity that the correlations of thought can reach, the aforesaid process requires a huge capacity of working memory. The task of procedural memory may also be very difficult. All of this could be one of the main reasons for the huge differences between human thought/language and animal thought/communication. In order to deal with this subject, I use a very simple example. Let's imagine that we have two objects, like the ones in Picture 8.



Picture 8.

It is very likely that a lot of animals can perceive an apple or a leaf. Amongst the motor activities that the animal can perform, there is the activity of producing sounds when a certain object appears in its visual field (or other perceptual field). These sounds can be recognised by some other animals of the same species making them direct their attention so that they too can perceive the object. All of this is surely a form of communication. Yet research in linguistics and psycholinguistics has repeatedly stressed that this form of communication is different from human language in some fundamental features, one of which is that in animal communication the number of objects that can be indicated is very limited and fixed and the relationship between a certain sound and a certain object is fixed too [Yule 1996].

According to OS, a *fundamental difference between human mind and animal mind* could be the fact that the former has:

- 1) an *attentional activity* that is *much more sophisticated* than the latter;
- 2) an activity that is probably absent or almost absent (at least spontaneously) in animals: the *production of mental categories and correlational network*.

The very sophisticated human attentional activity allows humans to *fragment* their experience in a far richer way than animals. In the aforesaid example, humans can isolate the perceptions “apple” and “leaf” (that is, two specific shapes, which are different from the shapes of any other object) from two other perceptions, the colour “red” and the colour “green”. Humans can do the same in innumerable other situations: they can isolate the action of “flying” from the object “bird”, the meaning of the adjective “hard” from the object “stone”, etc. As a result of this process of fragmentation, many single different meanings are created.

Then, at the level of thought, correlators allow humans to perform a *recombination* of these many single different meanings, thus generating sequences (that is, sentences) that can be made up of many of them. In this way humans, by means of a number of words that is *limited* (even if rather big: the words that designate the aforesaid many meanings that have been created, i.e. the lexicon of a language), can produce an *unlimited* number of utterances,

that is, they can describe *any* experience. For instance, with the words in our very simple example, they can describe, besides a red apple and a green leaf, a green apple and a red leaf too. *The aforesaid two processes, the one of fragmentation and the one of recombination, are, according to OS, the essence of human language.*

All of this implies a huge advantage from an evolutionistic point of view. In this way, human beings have acquired the ability to tell each other any experience they have. Therefore, a huge accumulation of notions becomes possible for every human being, with the only limit of the long-term memory capacity.

7. THE GRAMMATICAL TERMS ACCORDING TO OPERATIONAL SEMANTICS

The correlational theory of thought allows us to give an easy definition of some grammatical terms that have always been considered fundamental, but have always been very difficult to define.

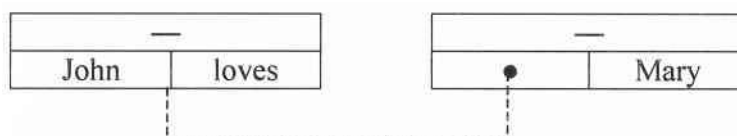
One such concept is “subject”. While everyone is able to identify the subject of a sentence, all the definitions that have been suggested up to now in some cases fail to identify it. For example, the semantic definition (“subject is who/what performs the action or is in the state expressed by the predicate”) fails in identifying the subject in the passive sentences (for example, “Tom was arrested by the police”); the morphosyntactic definition (“subject is what triggers agreement morphology on the verb”) does not work in languages where this morphological agreement is (partially or totally) missing (however, as regards this definition we might also object that this agreement, when it exists, presupposes that the speaker *knows* which is the subject); the definition of subject as “what is being talked about” (or “topic”) fails in sentences such as “The little girl, someone hit her”, where the topic is not so much “someone” (that is, the subject) as “the little girl”.

On the contrary, thanks to the correlational theory of thought, OS offers a definition of “subject” and “object” that works always. According to OS, **subject** is what is focused on by attention, and kept present, *before* the verb; **object** is what is focused on by attention *after* the verb, which is kept present. We can easily see this different temporal setting in a couple of expressions such as, for example, “the wheel rotates” and “rotating the wheel”: in the former expression, what we see before is the wheel, while in the latter it is the act of rotating. In other words, “subject” is the first correlatum of a correlation whose correlator is presence keeping and whose second correlatum is a verb; “object” is the second correlatum of a correlation whose correlator is presence keeping once again, and the first correlatum is a verb. Therefore, in our examples, we have the following structures:

—	
(the) wheel	rotates

—	
rotating	(the) wheel

In the case of a sentence made up of a subject, a verb and an object, such as, for example, “John loves Mary”, the structure is the following:



These definitions work perfectly in the aforesaid examples where traditional definitions fail. Moreover, they agree perfectly with two facts: a) languages where the order of subject, verb and object is either SVO or SOV or VSO (that is, where the subject *precedes* the object, like in the correlational network of thought) are almost the totality of languages of the world, while the ones that have one of the other three possible orders (where the subject *follows* the object, contrary to what happens, in our opinion, at the level of thought) are extremely few; b) the languages that put the subject in the first position (SVO e SOV) are the very great majority [Dryer 2005; Graffi, Scalise 2002, p 68].

Another grammar concept that has been always considered necessary and fundamental is the “noun”. Yet, the definition of this concept has always been a big problem as well. School grammar books generally provide a semantic definition by stating that nouns are the words that indicate “persons, animals, vegetables, unanimated objects”. Some books also add “qualities, quantities, ideas”, or “places, events” and so on. The “verb” category (which is the main category in contrast with the “noun”; nevertheless, the infinite forms of the verb, i.e. the infinitive, the participle and the gerund, are commonly called “nominal forms”) is also generally defined in a semantic way: verbs are said to designate “processes or states”. Contemporary linguistics is perfectly aware that these semantic definitions are unsatisfactory: for example, a word such as “birth” designates a process, but it is a noun, not a verb; words such as “to be born” and “outside” are a verb and an adverb respectively, but they designate an “event” and a “place” respectively, which are among the things that nouns are supposed to designate. In general, we can say that many languages have a great many pairs of words which, like “to be born” and “birth”, have the same meaning, where one is a verb and the other a noun (unlike English, where there are fewer such morphologically different pairs and often the same word has both functions).

Contemporary linguistics has therefore tried to go beyond these semantic definitions. In general, it has tried to give functional definitions and/or definitions based on the relationships among the parts of speech. In order to give an idea of these kinds of definitions, the noun, for example, is said to be what occurs with articles and attributive adjectives (that is, the adjectives that are part of a noun phrase headed by the noun they modify, such as “happy” in “happy years”) and is the head of a nominal phrase. Nevertheless, these definitions are partially not applicable in some languages (for example, Russian and Latin do not have articles), are partially tautological (“*nominal* phrase”) and easily end up being circular (the noun is defined in terms of its relationships with the article and/or adjective, and the latter two can be defined, either directly or indirectly, in terms of their relationship with the noun). Apart from this, even if a definition of this kind works (i.e. it identifies words that are sensed as nouns), the two following objections are still valid: a) we can say that the definition works exactly because *we already sense* very well which words in a sentence are nouns, even if we do not know how we do this (the theory that we record these reciprocal relationships and/or functions unconsciously is not very convincing, because it involves an unconscious elaboration that is rather complex and incompatible with a circular identification of the

various parts of speech); b) the fact that nouns occur with certain other parts of speech however does not explain *what nouns are*, i.e. what their *nature* is.

The real problem is not giving a definition of “noun” that works, i.e. that always identifies which words in a sentence are nouns. *The real problem is understanding why we sense very well that in speech there are words that all belong to the same class*, which is called the class of “nouns”. If we understand this, the definition of “noun” comes automatically.

OS provides a simple and natural solution to this problem. We have to note that:

- 1) conjunctions, prepositions and the verb in the personal form are never nouns;
- 2) the verb in the infinitive forms is a noun instead (for example, “reading books”);
- 3) the adjective has always been considered a noun (the present-day substantive/adjective distinction was absent in the Greek and Latin grammar but was introduced during the Middle Ages and the expressions “substantive nouns” and “adjective nouns” have been used for a long time since then [Robins 1997 p 106-7 It ed]; in linguistics, adjectives are commonly considered “nominal forms” as are substantives).

According to OS, the grammar category of **noun** is based on the fundamental distinction between *correlators* and *correlata* (section 6), i.e. between elements of linguistic thought that have the function of linking and elements that are linked by the former. Nouns are the *mere correlata*, i.e. the words that designate something which *has no relating function*, unlike the words or morphemes that designate a correlator or *also* (see below) a correlator. Nouns are therefore the meanings which, in the graphic representation of the correlation triad that we use, are *exclusively* placed in one of the two lower boxes, unlike the meanings that are placed or are also placed in the upper box. Therefore, according to OS the grammatical category of “noun” *can be defined only by using the position the word has in the correlational network (i.e. its function) as a criterion of classification, not by basing ourselves on a semantic criterion*. For example, the words “John”, “piece”, “glass”, “doors” and “windows”, which are mere correlata in the following correlations:

—	
John	reads

of	
piece	glass

and	
doors	windows

are nouns. The adjective also indicates a mere correlatum, as we can see in this example:

—	
red	book

Instead, the **verb in the personal form** is never a “noun”, because it does not simply indicate a correlatum (thus it is not a “*mere correlatum*”), but it designates a good four things:

- a correlatum;
- a particular correlator, the presence keeping (therefore, it indicates both a correlatum *and a correlator*);

- the position of the correlatum, which is the one of a second correlatum;
- that the first correlatum is what grammar calls a “person” (that is, the agent or the “addressee” of the linguistic interaction, or another person/thing [Graffi & Scalise 2002 p 193]), and the kind of this person (first, second, third, singular, plural, etc).

That is, for example, the personal form of the verb “to laugh” *laugh-s* indicates that the verb has to be related to a third person singular. Therefore, “laughs” is not a *mere* correlatum, but designates a *whole* correlation, i.e. the following:

—	
a third person singular	laugh

Instead, the verb in the infinitive mood is a mere correlatum, as in the following examples:

—	
to be	strong

—	
reading	books

Therefore, in this case the verb is a noun. Thus, the noun/verb distinction does not have a semantic basis, but depends on the function of the meaning in the correlational network: the same meaning and, depending on the language, the same word, can be either a verb or a noun, as in the following examples:

—	
I	run

—	
long	run

Do not be misled by the fact that the *position* of the word “run” is the same in both correlations: its *function* in the two correlations is different (this is *not* shown by the graphics we are using—this would have been too complicated). In the first correlation, the word “run” is a first person personal verb. English does not indicate this in any way, and we can only deduce this from the fact that the correlation of the personal pronoun “I” with the word “run” as a noun would have no sense. Since “run” here is a personal verb, it indicates a correlatum, its position of a second correlatum, the correlator “presence keeping” and that the first correlatum is a grammatical person, as we have said. In the second correlation, the word “run” cannot be, based on the general sense of the expression, a personal verb, therefore it indicates a correlatum only, not all of the above. That is to say, it is a noun. Other languages do not rely on the general sense of the expression, but indicate if a certain meaning is either a noun or a verb in the personal form in a morphological way. For example, French would say *je cours* (“I run”) and *longue course* (“long run”). The “-s” ending of *cours* indicates a good five things: 1) that the meaning of the theme *cour-* (which is the theme of *course* too) is not isolated, but is linked to something by means of the presence keeping; 2) its position is that of a second correlatum; 3) the first correlatum is a first person; 4) thus, since *cour-* is a personal verb, its mood is the indicative and 5) its tense is the present.

Other fundamental grammatical terms are “substantive” and “adjective”. According to OS, the **adjective** designates something that does not exist independently, but is necessarily tied to something else, from which it can be isolated by means of the selective ability of attention (this generally also applies to the verb, which nearly always refers necessarily to an agent (for a definition of the meaning “agent”, see further on), but, as we have seen, the verb requires a prolonged attentional focalization, which makes it a category apart). On the contrary, the **substantive** designates something that exists (or is considered) independently. For example, the meanings of words such as “tall”, “green”, “hard” do not exist as independent things (unlike the meanings of words such as “man”, “leaf”, “stone”), but are necessarily tied to something, which owns them as features, and are only obtained by means of a mental operation of separation.

The substantive-adjective correlation is:

—	
green	leaf

The definition that we have just given to the grammatical category of “substantive” and the one that we gave to “verb” (previous section, p 17) easily explains the fact that having both these categories is a linguistic universal (one of the few ones [Yule 1996 p 277 It ed, Graffi & Scalise 2002 p 117])¹².

8. ANALYSES OF THE OTHER FUNDAMENTAL MENTAL CATEGORIES

Correlators

The first meaning of a correlator that will be examined here in linguistics is commonly called “genitive”, from the name of the case that expresses it in the classic Indo-European languages. This meaning is expressed in English by means of the preposition “of”, the possessive case, and word order. Although this meaning is not included in the two lists that were chosen to identify the fundamental mental categories, in linguistics it is generally considered fundamental (in English, the preposition that designates this meaning, “of”, is the most frequently used preposition and the second most-used word).

Just like every correlator, the genitive ties two correlata, the one that is present first at the level of thought (first correlatum) and the one that is present after (second correlatum). The principle that the order at the level of thought is mirrored in the word order of speech is valid for the correlators that we have considered until now and, in many languages, generally for all correlators. That is, the word that expresses the first correlatum precedes the one that expresses the second correlatum. This is not always the case however. There are many languages where, since they often express the correlators by means of a case mark, an inversion of the aforesaid order is allowed. For example, the English expression “the walls of the town” can be translated into Latin both by using the order of thought (*moenia urbis*) or by inverting it (*urbis moenia*). Furthermore, some languages can express the meaning of the

¹² The correlational theory of thought, with its implications, as it has been exposed in the two last sections, is essentially Ceccato’s own. Only some modifications and additions are my own.

genitive exactly by inverting the order (for example, in English, “safety belt”), or in some cases apply the inversion anyway (for example, still in English, the so-called “possessive case” involves the inversion [“John’s car”]). Therefore, in the case of genitive, which is the first and which is the second correlatum could be unclear. This calls for an explanation. The first correlatum (which we shall call *A*, as before) of the genitive is the one that in English precedes the preposition “of”, the second correlatum (*B*) is the one that follows it.

Having explained this, the meaning of the correlator can now be analyzed. The **genitive** indicates the attentional focalization of something, *A*, while keeping in mind that *A* has been previously focused on together with something else, *B* (this analysis is my own).

If we wish to make a comparison with the correlator “with”, we can say that, while “with” designates a sort of “addiction”, in the sense that the attention, after focusing on *A*, includes *B* too, the genitive designates a sort of “subtraction”, in the sense that, of the whole *A+B* that is kept present, we take *A* into consideration. For example, if, looking at a man with a black hat on his head, we say “there is a man with a hat” and then add “the man’s hat is black”, in both cases the attention has focused on the man and the hat together, but when using the genitive the attention focuses then only on the hat (in order to talk about it and say that it is black).

The genitive is used in many cases, that is, the relationships between the things that it correlates are many. The classifications used in linguistics are more or less similar to the following:

- various kinds of possession (for example: “John’s eyes”, “John’s car”, “the diameter of the sphere”) and association (“the sound of the trumpet”, “the paintings of Raphael”, “1929 recession”), relationship indicated by the noun being modified (“John’s wife”);
- belonging to a group (“three of us”);
- composition (“marble statue”, “group of men”), containing (“a glass of water”);
- participation in an action, as an agent (“John’s arrival”) or as a patient (“the discovery of America”);
- origin (“men of Rome”);
- cause (“to die of tuberculosis”);
- purpose (“safety belt”);
- quantity (“a height of 100 m”);
- quality (“man of honour”);
- denomination (“the city of Rome”);
- plenty or lack (“full/devoid of malice”);
- topic (“grammar book”), in respect to (“slow of speech”);
- fault, accusation and similar things (“guilty of murder”);
- age (“a child of four years”).

All these cases confirm our analysis that the first correlatum is focused on while keeping present that it has been focused on together with the second correlatum. The fact that the genitive simply indicates, in an *extremely general* way, that its correlata have been focused on together by the attention, clearly explains the fact that the relationships that there can be

between the two correlata of the genitive are many, and that it can be used in very many cases.

Therefore, the relationships between *A* and *B* are the ones where *there is no interruption in the attentional focalization*, such as those designated by the preposition “with” (“cup with handle” → “the handle of the cup”) and the verb “have” (“that man has a moustache” → “the man’s moustache”). The implicit correlator also designates a relationship of this kind. Therefore, the genitive can be used when one of the following relationships occurs: substantive-adjective (“white wall” → “the whiteness of the wall”), subject-verb (“John runs” → “John’s running” [so-called “subjective genitive”]) and verb-object (“choosing the cards” → “the choice of the cards” [so-called “objective genitive”]¹³), verb-adverb (“moving slowly” → “the slowness of the moving”)¹⁴. If there is an interruption in the attentional focalization (that is, in practice, there are two attentional focalizations), as in the case of the conjunctions “and” and “or”, and the link is only given by the presence keeping (PK), then the genitive cannot be used, because there is no relationship between the two things, and it is we who link them (for example, after having said “on the table there is a bottle *and* a cork” we cannot say “the cork *of* the bottle”, while we can do this if the first sentence was “on the table there is a bottle *with* a cork”).

The fact that the genitive (“*A of B*”, such as “bottle of wine”) indicates that attention focuses *first on A* together with *B*, *then only on A*, can probably also explain why some languages (such as English) can express this meaning by means of the word order *B-A* (“wine bottle”).

It is important to note that, in practice, the use of this mental category often has the result (and the purpose) of identifying something, belonging to a certain class, by means of something else that has been focused on by attention together with the former. For example, expressions such as “the panes of the window”, “John’s car” etc identify a certain item belonging to a certain class (perhaps this is the reason why the ancient Greek grammarians coined the term “genitive”, i.e. “that concerns the genus [or class]”, for this case). An example where this is clearer can be “the fireplace of the hall” vs “the hall of the fireplace”: the former expression implies that there are at least two fireplaces and the hall is used to identify one of them, the latter that there are at least two halls and the fireplace is used to identify one of them. This explains why the two correlata of this correlator can be inverted in rare cases only, i.e. when *B* can be used to identify *A* and vice versa (“glass bottle” and “glass of a bottle”, “the bottle of the wine” and “the wine of the bottle” etc), but not when this does not happen (“the buttons of the jacket”, but not “the jacket of the buttons” etc). In the cases of the second kind, if we want to speak of the first term, we just put it as the first correlatum and designate its relationship with the second (“the jacket with the buttons”).

Correlations can also be made on the “maps”, which means designating the position of something with respect to something else. The operations that these correlators designate are

¹³ Note that in the objective genitive it is the *first* correlatum of the starting relationship, that is, the verb (“choosing”, in our example), that becomes first correlatum in the correlation that has the genitive case as correlator, not the *second* correlatum, as happens in the other cases. These is due to the fact that, if the patient becomes the first correlatum (that is, subject) of the verb of which it was before the object, we have the passive form of the verb (see further on): in our example, starting from the expression “choosing the cards” we have not “the cards of the choice”, but “the chosen cards”.

¹⁴ Note that in this passages the first correlatum of the genitive case becomes always a substantive, even if before was not (“white wall” → “the whiteness of the wall”). Naturally, this is due to the fact that it is considered in isolation (see the definition of “substantive”, p 30).

obvious: we shall mention them for the sake of completeness only. At least two things (objects or activities) are involved, *A* and *B*.

The structure is the general one of correlators, that is, *A* is focused on by attention (AF) and kept present (PK) while the attention focuses on *B*.

When there are two correlata, *A* and *B*, the part of the “map” that corresponds to *A* can be a part of the part of “map” that corresponds to *B* (preposition **in**) or not (preposition **out of**).

If we relate a thing (*A*) not with another thing, but with two or more other things (*B*, *C*, etc), there is also the possibility designated by the preposition **between/among** (the attentional focalization of *A* takes place in the area(s) encountered when passing directly from *B* to *C* etc (the distinction between two things/more than two things, which English makes, is not present in other languages).

When correlating something (*A*) to something else (*B*) on a “map”, if we take, as a reference, the vertical or the horizontal direction (both passing through *B*), we obviously have the categories that correspond to “right/left” and “up/down”, but that designate correlators (**on the right/left of** and **on** (or **over**¹⁵)/**under**, respectively).

The operations corresponding to the categories “in”, “out of”, and “between/among” can also be performed on the temporal “map” or other “maps” (for example: “*in* the past”, “a pause *in* the speech”, “*in* this series of numbers”, etc; “*between* 9 and 10 o’clock”, “*between* the subject and the verb”, “*between* 2 and 4”, etc). The structure of the category “out of” also allows it to be used on the temporal “map”, but, since this “map” is asymmetric, what happens “out of” a given time is made up of two phases that are clearly distinct, the one that precedes and the one that follows that time. Therefore, the word “out”, when referred to time, can only be used in rare cases where the time before and the time after are equivalent, such as in the expression “out of time”.

In a “map”, following some activity by attention (first correlatum, *A*) can also involve the shifting of the attentional focus with respect to something else (second correlatum, *B*). The two possible directions of this movement, which we may call “moving away” and “approaching” and/or symbolise by the symbols $A \rightarrow$ and $A \leftarrow$, are naturally indicated by the prepositions **at/to**¹⁶ and **from**.

The analyses of the correlators that we have just considered are, as we said, obvious. The meaning of another preposition (found in various languages), which is in some ways similar to the preposition “at/to”, i.e. the preposition “for”, is less obvious. Some observations should also be made about the three prepositions “at/to”, “for”, and “from” together. The preposition **for**, like “at/to”, designates attentional movement towards and/or entering into attentional contact with something, but differs from “at/to” because with “for” the contact is extended, prolonged or repeated, while with “at/to” the contact is restricted or single (to sense this difference, compare the two expressions “to look *at* something” and “to look *for* something”).

The aforesaid movements ($A \rightarrow$ and $A \leftarrow$) can take place on a spatial “map” (“going to Rome”, “coming *from* Rome”, “passing through [*for*”, literally, in other languages] Rome”) or a temporal “map” (“*from* 9 to 10 o’clock”, “he lived there *for* three years”) or a “map” of another kind (“he got down *from* the first to the last position of the hit parade, passing through [other languages use *for* instead of “through” in such cases] the intermediate ones”).

¹⁵ This distinction, which concerns the contact, can be found in English, but not in other languages.

¹⁶ This distinction can be found in English, but not in other languages and will therefore not be considered.

Maybe the aforesaid shifting of the attention is not so strictly related to a “map”. Cases of this kind are the following.

a) Preposition “at/to” — In many languages, this preposition is used after verbs such as “to give”, “to say”, “to bring” etc for the so-called “indirect object” (here English uses or can also use word order: “John gave a book to Mary” or “John gave Mary a book”). Adjectives such as “harmful”, “useful”, “near”, “similar” etc are also followed by “at/to” in many languages. This is due to the fact that in all these cases there is a shifting of the attention, as happens on the “map”. Other languages, such as Latin, use a case mark in both these cases, the **dative case**. In the passage from a language that has the dative case to a derived language that does not (from Latin to French or Italian, for example) this case is almost always replaced by the preposition “at”. This demonstrates that the preposition “at/to” and the dative case are substantially the same.

b) Preposition “from” — Verbs such as “to originate”, “to separate” etc also imply a shifting of the attention, as happens on the “map”.

The structures that we have suggested for the prepositions “at/to”, “from” and “for” explain their use very well. Let’s consider them one by one.

1) In addition to the above, the structure of “at/to” lends itself to indicate the following relationships:

- purpose (for example: “she has gone out to smoke”): while we keep the action of “going out” present, the attention enters into contact with the action of “smoking”, which is, in this case, the purpose;

- manner (“to be at one’s best”) and (in some languages, unlike English) means (for example, the French expression “jouer à la balle”, which is translated by the English expression “to play with a ball”, literally means “to play at ball”): while we keep the actions of “being” or “playing” present, the attention enters into contact with “one’s best” or the “ball”, which, in these cases, are the manner and the means, respectively;

- sometimes, the relationship of cause (“he was shocked at the news”): see further on;

- other relationships that are quoted by grammar books and dictionaries, such as advantage/disadvantage (“cheque to bearer”), measure/price (“running at 100 km/h”), comparison (“similar to”) etc, for which the same consideration applies.

2) We have hypothesised that the operations designated by “for” are similar to those designated by “at/to”, but differ because there is an extended, prolonged or repeated attentional contact with the second correlatum. This clearly explains four facts.

- The first is that both prepositions are used in some cases (“harmful to/for health”, “he was sorry at/for her departure”); in several languages this phenomenon is more widespread than in English).

- The second is that in some cases where a certain language uses “at/to”, another language uses “for” and vice versa (for example, the Latin expression *ad laudem insignis* is translated by the English expression “famous for his merits”). Similarly, in some cases where a language uses the dative case, a derived language that does not have this case uses “for” instead of, as happens more commonly, “at/to”. For example, Latin has the so-called “dative of advantage or disadvantage” (for example: *non solum nobis divites esse volumus*, “we do not want to be rich for ourselves only”) and the so-called “dative of reference” (*venientibus ab Italia*, “for those who come from Italy”). In a language that derives

from Latin such as French the preposition *pour* (“for”) translates these two kinds of dative case.

- The third is that we use “for” and cannot use “at/to” when the relationships are a prolonged contact in time (“he lived there *for* three years”) or in space (“passing through [*for*”, literally, in other languages] Rome”).

- The fourth is that both prepositions can indicate relationships of cause and purpose, but one of them does this better. In fact, we can find both prepositions to indicate cause (“he was sorry *at/for* her departure” and many other possible examples in other languages; “he was shocked *at* the news”, “I cannot see the road *for* the fog”), but the extended, prolonged or repeated contact that the preposition “for” is thought to express, can better express the “strength” of the causal relationship, which furthermore is often prolonged in time (“he got pale *for* fear”). In agreement with this, “for” seems to be used much more frequently than “at” when a relationship of cause is involved. Nevertheless, in cases where there is a causal relationship, but what happens exactly is a “single” contact (“he was shocked *at* the news”), we find “at”. We can also find both prepositions in the case of the relationship of purpose (“used to make/*for* making”; in several languages this phenomenon is more widespread than in English), but “for” expresses better than “at” the lasting attention on something when we pursue it as a purpose. In agreement with this, in this case “for” seems to be more used than “at/to”.

3) The structure of the preposition “from” lends itself to indicate detachment from something in space or time or another kind of “map” and origin as well as the following relationships:

- means, when the second correlatum is the origin of the first (for example, “he recognised her *from* the footsteps”);

- agent: the analysis of this meaning (see further on) perfectly explains the fact that, whereas some languages have a specific preposition or case mark, others, such as Italian, use the preposition “from” to indicate the agent in the passive construction of the sentence (for example, “*amato da tutti*”, “loved by everybody”, literally “loved *from* everybody”).

After analyzing the main prepositions (or corresponding cases; since a preposition and a case are only two different ways of expressing the same correlator, in this paragraph we shall only use the term “preposition”, for the sake of simplicity), we can more clearly understand the concept that we mentioned at the beginning of § 5, when the preposition “with” was considered. The meaning of prepositions that are strictly related to the “map” concept (both spatial and temporal, or “maps” of a different kind), such as “over/under”, “in/out of” etc, seems, as we stated, obvious (and substantially unique). For the others (such as “with”, “of”, “for”) it is a completely different matter. The problem of their meaning has always proved to be particularly difficult. Linguistics has generally supported the thesis of a complex polysemy. There are basically two theses: 1) these prepositions have many meanings; 2) these prepositions have no meaning of their own, and take a meaning from the context.

Both theses (explicitly the first, but also the second) maintain that these prepositions are polysemous. Actually, the relationships between the things that each preposition correlates are very different. In attempting to identify their meaning, dictionaries and grammar books have long lists of relationships for each preposition (for example, for the preposition “of”, they list the relationships: “possession”, “composition”, “containing”, “agent or patient of an action”, “origin”, “cause”, “purpose”, “quality”, “quantity”, “denomination” and so on, as we

have seen). Whether it is explicitly stated or not, these would substantially be the meanings of the preposition. In my opinion, it is highly unlikely that a preposition has so many meanings. In fact, this thesis disagrees significantly with the fact that words normally have only one meaning plus, possibly, a very few other meanings, namely the figurative, extended etc ones, which derive from the first meaning for easily understandable reasons (for instance, the term “nose” means a part of the face, but also snout, muzzle, shrewdness, the opening of a tube etc, a spy). Furthermore, the thesis that these are the meanings of the preposition disagrees with the fact that in several cases *the same* relationship can be expressed by *different* prepositions (for example, in both the expressions “to be in bed *with* a fever” and “to be shocked *at* the news” the relationship is cause).

As mentioned, OS instead suggests the thesis that these prepositions *do not designate such relationships*, i.e. these relationships are not *the meanings* of the prepositions. These prepositions designate *much more general* relationships, which allow/induce sequences of mental operations, amongst which the ones of attention play a key role. We have proposed the analyses of such sequences. These very general relationships *include* the aforesaid more specific relationships (which depend on the two related things), but the meaning of these prepositions is only given by the first relationships, not the second. Therefore, *the meaning of these prepositions is only one*, in principle.

The aforesaid more specific relationships are designated *by the whole* that is made up of the preposition and the things that it correlates. This designation is often *partially implicit*, in the sense that, starting from the precise (and unique, in principle) meaning of the preposition and those of the two things that the preposition correlates, our general knowledge tells us what relationship is involved (cause, time, manner etc). This thesis is proven by the fact that, if we consider *isolated* correlations, so as to limit the importance of the “general knowledge” factor as much as possible, we can find cases of ambiguity, such as “Smith’s book” (possession or relationship work/author?), “love of God” (an objective or subjective genitive, that is, does God love or is God loved?), “invisible for the crowd” (cause or limitation?), etc.

As we can see, OS therefore differs greatly from previous theories in linguistics about the meaning of these prepositions.

The correlator **because** in the two lists of fundamental words chosen above, expresses an extremely important notion, the so-called **efficient cause** (**cause**, as a substantive; as a correlator, many languages also use, as we have seen, the more general meaning expressed by the preposition “for”). Naturally, we are not interested in the philosophical or scientific problems that are related to this notion (the dualism case/necessity, the existence of a “first cause” etc), but simply in the mental operations that are designated. In my opinion, these are:

- 1) in the temporal operational scheme (TOS), attention focuses (AF) on two things (that is, two events), A and, subsequently (or, at the best, simultaneously), B;
- 2) this experience is kept present (PK) while we perform
- 3) an operation of representation (R) of the absence of B in the hypothesis of an absence of A, a representation that is induced by the memory (MO) of experiences that are equal (or similar) to the present one, i.e. experiences where the absence of events that are equal (or similar) to A is followed by the absence of events that are equal (or similar) to B (such experiences are eventually summarised in a general law).

The operation in point 3 is *necessarily* a *representation*, that is, something *intrinsically uncertain*. In fact, there can be two or more events that are equal (or similar) to each other, but, since a given event is by definition associated with a specific moment, *it cannot repeat itself any more*, precisely because of the passing of time. In other words, we can observe one or more events that are *equal* (or similar) to a given event, but we can *never* observe *the same* event more than once. Because of this, it is impossible to perceive/establish the existence of causal relationships with certainty (as stated by Hume). In order to determine a causal relationship *with certainty*, we should be able to go back in time and remove the supposed cause of a certain effect. This is impossible of course. We can only infer the existence of a causal relationship on the basis of equal or similar experiences. This lies behind the well-known unavoidable uncertainty of causal relationships in history (where no events are the same because each event is strongly associated with different people) and the certainty beyond any reasonable doubt of causal relationships amongst repeatable phenomena that are ascertained with the experimental method. Therefore, causal relationships are not *inexistent*, that is, illusory (Hume), but, *strictly speaking, not ascertainable* (even if for those where the phenomenon is repeatable the doubt is not reasonable).

In the case of the so-called **final cause (purpose** as a substantive, **so (that), so as, in order that, in order to**, as a correlator; English and many other languages also use the more general meaning expressed by the prepositions “for” and “to”, as a correlator, as we have seen), the meaning, i.e. the operational scheme, is the same as the efficient cause (in fact, the term “cause” is used in both cases). However, in the final cause the cause is given by will, whose object is “purpose” (for the meaning of “will”, see further on). In fact, we can always change a final clause (for example, “I study to learn”) into a causal clause introducing will as a cause (“I study because I want to learn”). Since in the final cause the cause is the will, the final cause presupposes, as an agent, a being that has will or at least a finalistic behaviour (for example, “the plant has grown in this direction to find light”). In fact, unanimated objects are excluded.

Let’s consider the conjunction “if”. Grammar books distinguish the so-called *conditional* “if” (e.g. in sentences such as “if you study, you will learn”) from the so-called *dubitative-interrogative* “if”, which is used in dubitative and indirect interrogative sentences (e.g. “I do not know if I shall go”, “tell me if you will go”). Nevertheless, linguistic data, as a whole, show that there must be a strong affinity between the two kinds of “if”. In fact, in the various languages the conditional “if” and the dubitative-interrogative “if” can be expressed: 1) always by the same word (as in French: *si*); 2) by different words, but also by the same word (as in English, which uses *if* and *whether/if*, respectively); 3) by different words, but with the possible presence of indications that suggest an affinity (for example, Latin does not use the word that expresses the conditional “if” [*si*] to express the dubitative-interrogative meaning, which is expressed by the enclitic particles *-ne* or *num* in the simple indirect interrogative sentence, and *utrum...an* [“whether...or”] in the double indirect interrogative sentence; nevertheless, in the latter we can also find *sive...sive*).

Let’s take two very simple examples of the two kinds of “if”, where the governed clause is the same.

- *You will see, if you will go* (conditional “if”)
- *Tell me if you will go* (dubitative “if”)

In *both* cases the **conjunction** “if” designates an alternative in the operation of representation, i.e. on the one hand, we represent the meaning of a clause (A) and, on the other, keeping this meaning present, we discard it (the latter operation is, as we have seen, the negation).

In the case of the conditional “if” *only the meaning A* (that is, the eventuality “you will go”, in our example) is correlated (as a second correlatum) to another clause (“you will see”). In the case of the dubitative-interrogative “if” *the whole alternative A/not-A* is correlated (still as a second correlatum) to another clause (“tell me”). The languages that use the same word in both cases rely on the fact that the meaning of the main clause is sufficient to settle the ambiguity: if an alternative is implied, then the dubitative-interrogative “if” is involved.

Interrogative-Relative-Indefinite Pronouns and Adjectives

We have stated that the categories “who”, “what” and “which” (and “where”, “when” and, as we shall see, “how” as well) designate that attention selects an *unspecified item* (A_x) belonging to a group of items that are considered equal to each other (A₁, A₂, A₃,...). Therefore, they substantially designate *an unsolved alternative*. The result is that, even if put into a correlation, they give a “sense of suspension”, which is not present in other correlations. Compare the two expressions “yellow flower” and “which flower”. These two correlations are equal.

—	
yellow	flower

—	
which	flower

The expression “yellow flower” means that a *definite* thing (a “flower”) has a feature (what the adjective “yellow” means), which is also *definite*. Therefore, in this sense, the expression is *accomplished*. The expression “which flower” instead indicates that, given the class of flowers, we have to select *one*. Therefore, *it is not definite*, and, above all, actually remains an *isolated* substantive, that is, a substantive that is not correlated with an adjective or a verb (i.e., from this point of view, saying “which flower” is no different from simply saying “flower”). Hence this sort of “sense of suspension”. Note that this sense of suspension remains even if the adjective “which” is correlated with something unique (therefore, well identified) such as a proper noun (for example, “John who...”. In this case, the adjective has the effect of “making plural” even the proper noun, because the expression “John who...” means “John, in *a particular* moment or attitude etc of the *various* possible moments or attitudes etc (for example, “John who laughs”).

This particular meaning clearly explains how we can use these categories.

1) Since these categories substantially designate an alternative, it is possible to correlate *two* (or more) things to it, by repeating the word that designates the category: this is the use of **who/what/which as indefinite pronouns/adjectives** (for example, the Italian sentence *chi parlava, chi taceva* [“some spoke, some were silent”], which literally means “who spoke, who was silent”). This use is not present in all languages, because it is the same as using the more specific (and more appropriate) term “some” (for this term, see further on):

some languages, such as English, use the latter term only, other languages, such as Italian, have the alternative.

2) It is also possible to correlate something to the category and try to eliminate the alternative, that is, try to identify A_x : this is the use of **who/what/which as interrogative pronouns/adjectives** (for example, “who knocks?”; for the meaning of the interrogative form, see further on).

3) Finally, it is possible to insert the category, after having correlated it with something, in another correlation: this is the use of **who/what/which as relative pronouns/adjectives** (for example: “those who heard laughed”). In this case, the person who the pronoun “who” refers to remains unspecified, but, whoever he or she is, he or she becomes the correlatum of something else definite, so that the aforesaid “sense of suspension” stops. It is important to note that when “who/what/which” are used as relative pronouns/adjectives, they designate *not one but two* elements of the correlational network, that is, both a correlatum (as in cases 1 and 2) and a correlator, the presence keeping (we have seen that the verb in the personal form also acts in this way). Therefore, the correlational networks that correspond to the two sentences:

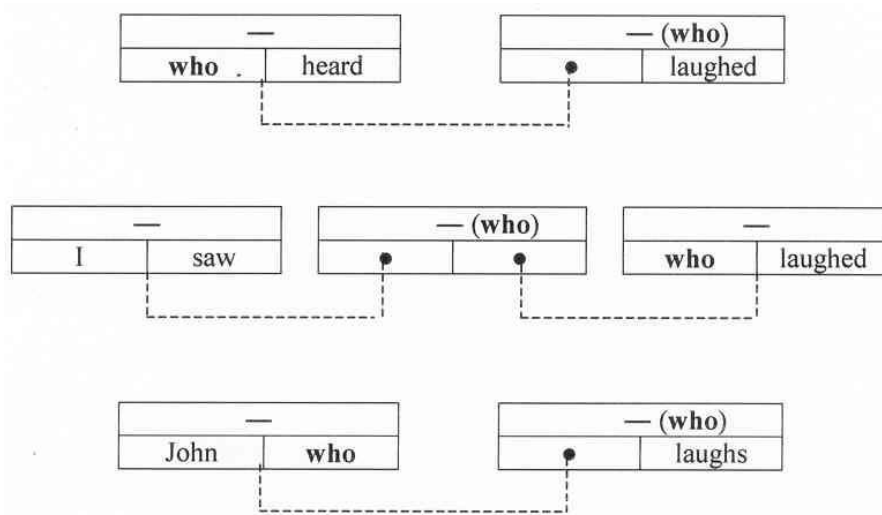
4)

- *Who heard laughed*
- *I saw who laughed*

and the relative clause

- *John who laughs*

are the following (the double role of the relative pronoun has been highlighted by means of a bold font):



These statements about the uses of “who/what/which” also apply to “where” and “when” (and “how”, which, as we shall see, is based on the same operations).

The distinction that grammar makes amongst indefinite, interrogative and relative pronouns/adjectives (cases 1, 2, and 3, respectively) is therefore more a *use* than a *meaning* distinction. The meaning of the pronoun/adjective *is still the same*. This agrees perfectly with the fact that in many languages it is designated by the same word or theme or root.

How and Adverbs of Manner

The meaning that is expressed, as a substantive (that is, when we designate it in an isolated manner), by the term **manner** (or **way**) and, in the adverbs, in several languages, by a suffix (**-ly**, in English), is very similar to the meaning of the grammatical category of “adjective” (which has already been examined), and has the same relationship with the verb that the adjective has with the substantive. We have said that the adjective indicates something that does not exist independently, but is necessarily tied to something else, from which it can be isolated only mentally, using the selective ability of attention (while the substantive designates something that exists, or is considered, independently, i.e. in an isolated manner). In the same way, “manner” is something that attention finds tied to a meaning of a verb and which is separated by it mentally, using the selective ability of attention. For example, the meanings of words such as “slowly”, “strongly” etc are not already isolated, but are necessarily tied to something (which is often a verb) that owns them as features, and are obtained by means of a mental operation of separation. The close analogy between what grammar calls the “adverb of manner” and the adjective is confirmed by the fact that in many languages, such as English, the large majority of words that designate adverbs of manner are made up of the same word that designates the corresponding adjective plus a suffix (“sweet-ly”, “easy-ly” etc), and the fact that in some languages (for example, Turkish) the same word can usually be both an adjective and an adverb.

Since the nature of adverbs of manner is essentially that of being features, or qualities, of something else, they can refer (although the term “adverb” clearly derives from “verb”) not only to a verb, but also to an adjective (“a *really* beautiful flower”) and another adverb too (“he is *really* poorly paid”). Therefore, because of its etymology, the term “adverb” is rather inappropriate. From the semantic point of view, it would be better to say that there is a class of words that designate “qualities” (or “features”, or similar terms), which can be:

- 1) *qualities of substantives* (“beautiful flower”): *adjectives*;
- 2) *qualities of verbs* (“he is poorly paid”): (*appropriately called*) *adverbs*, which are generally morphologically distinct from 1, but sometimes identical;
- 3) *qualities of adjectives* (“a *really* beautiful flower”): hence, “qualities of qualities”, that is, qualities of the qualities in point 1; in order to designate these, *the same forms as in point 2* (so-called “adverbs”) are used (in English and in other languages);
- 4) *qualities of (appropriately called) adverbs* (“he is *really* poorly paid”): “qualities of qualities” as well, that is, qualities of the qualities in point 2; in order to designate these, *the same forms as in point 2* (so-called “adverbs”) are used (in English and in other languages).

As stated, the word **how** designates the same basic operations that are designated by “who/what/which”, “where” and “when” (the attention selects an *unspecified* item (A_x) belonging to a group of items that are considered equal to each other [$A_1, A_2, A_3, \dots$]). In the case of “how” these items are “manners”. Therefore, this term has the same fundamental uses that we have seen in the paragraph above for “who/what/which” (“where” and “when” have the same uses too), that is, the interrogative use (for example, “How did you do?”) and the relative use (for example, “I don’t know how he did”).

Quantity-related Words

The two lists of fundamental words include some words that seem clearly related to “quantity”. We have seen that “quantity” originates from a particular operational modality, which we could call “summative”. This consists of keeping in mind each item of a group of items that are considered equal for as long as the attention focuses on a new item (naturally, we can only keep a limited number of items in mind, but it is possible to count up to an indefinite number simply by remembering the name of the number of the last item that we have named: the following name originates from the former on the basis of a rule, which is partially recursive). Besides the word “number”, some words that designate single numbers and the verb “to count”, which have been already examined, the words that seem related to quantity in the “semantic primitives” of NSM and the Swadesh list are: “much/many”, “few”, “some”, “part” and “all”.

Let’s consider the categories “many”, “few” and “some” (the latter two as plurals) first. The first of the two categories (“many”) can be used in a relative sense, and the second (“few”) is always, or almost always, used in this sense. That is, the same number of items can be considered “few” or “many”. For example, 10,000 persons who take part in a demonstration are “few” if 100,000 were expected, or “many” if 1,000 were expected. Even four or five items can be considered “many” in some situations: for example, if someone has four or five pens in his or her pocket, they are “many”. Therefore, the categories **many** and **few, in a relative sense**, obviously designate a quantity that is more or less (operation of comparison), respectively, than a reference quantity.

The word **some** seems to mean both an “unspecified quantity” and an “unspecified, but small quantity”. The latter varies between a lower limit that is not clearly specified, but seems always, or almost always, to exclude the first four-five numbers (these quantities are generally indicated by their precise number: for example, “there were two/three/four/five persons”), and an even hazier upper limit, which does not seem to go far beyond the first dozen. Beyond this limit the quantities that are not precisely defined, are indicated by words or expressions such as “dozen”, “about twenty”, etc, or the word **many, in an absolute sense**, which generally seems to exclude the first dozens. In my opinion, we can use the following observations to explain these terms. It has recently been suggested that our brain, as well as the brain of several animals, has some innate mechanisms that allow us to count, even if *approximately*, in a, so to speak, “automatic” way, that is, without performing the relatively complex operation (in fact, children learn it more or less at the age of three) of counting in a precise way, i.e. associating a precise word of a rigorously determined series to each equal item that is found. In fact, various research findings have shown that several animals are able to distinguish quantities approximately. For example, from two little batches of apples,

macaques choose the one that has more apples. This ability improves the more the difference between the two numbers and the more the numbers become smaller. In animals, this becomes imprecise when there are more than three objects, and no animal is able to distinguish ten objects from eleven. At the neurophysiological level, it has been shown that the brain of monkeys contains neurons that are active when there are one, two, three, four, five objects, and these activation phenomena become less precise as the number increases. It has been suggested that these neurons also exist in human beings, and we continue to use them, regardless of the fact that we acquire, by means of knowledge, the ability to count in a precise manner. This is supported, along with some neuro-anatomical and neuro-imaging data, by research performed on a human population (the Mundurucu tribe in Amazonia) whose language has very few words to express numbers. In fact, the Mundurucu do not have names for the large numbers and only have five names for the small numbers (1, 2, and three names that are used for quantities from 3 to 5, from 3 to 8, and from 5 to 12, respectively), as well as the words for “some” and “many”. These natives have no knowledge of mathematics and cannot even count over the number two in a precise manner. Yet they are not different from educated western adults in the ability to estimate quantities approximately, such as telling which is the greater of two groups of items at first sight [Dehaene 2005]. The aforesaid hypothetical mechanism that allows us to count automatically explains, in my opinion, the aforesaid terms. As long as the mechanism is precise (five-six items), the quantities are indicated by the precise number (we should also note that the number “two” has a particular position with respect to all other numbers, because in order to realize that there are two objects which are considered equal *only one* operation of comparison is necessary. In fact, even in the Mundurucu restricted vocabulary of numbers, the word that corresponds to “two” indicates a precise quantity). Beyond the limit of five-six items the mechanism starts to become imprecise, so the word “some” is used; between one and three-five dozen the mechanism becomes even more imprecise, but still allows a distinction in the order of magnitude of dozens. Even further on the mechanism becomes highly imprecise, so the word “many” is used (the fact that the mechanism becomes *progressively* more imprecise explains why the upper limits of the categories “some” and “many” are hazier than the lower limits).

Let’s examine the categories “all” and “part”. With a group of items, it is possible to keep this group present and focus our attention on it again, while performing an operation of attentional selection or not. In the first case we have the category **part**, in the second case the category **all** (as a plural). Therefore, when we use these categories the group of items is considered *twice*. This becomes evident if we build a sentence on purpose where the group of items is not sufficiently specified, such as the sentence “change *all* the words in bold type into italics”. In this case, we understand the meaning of the sentence perfectly (we have to keep into consideration the words in bold type that we find, without discarding any of them), but *before* performing this operation, we have to know on *which* set of “words in bold type” to perform it (which would be clear in a sentence such as “change all the words in bold type of this paragraph into italics”). In neither time when we consider the group of items is it necessary to count them or to know their number beforehand (for example, in the sentence “I respect all human beings”, knowing their number is not necessary; counting is only used, in some cases, to be sure that the group considered at time t_2 is the same as the one considered at time t_1). It is only necessary: 1) to consider the group in quantitative terms (that is, to apply the aforesaid operational modality, that of keeping the preceding items present as we add each new item); 2) that the group be specified, in order to know on which items to perform the

aforesaid operation of new attentional focalization, with selection or not (in our example, the speaker considers once again, without any selection, the group of the “human beings”, which is *previously given*, and makes it the object of the expression “I respect”).

In English, the singular of “many” is “much”, and the words “few” and “all” can be both a plural and a singular. That is, we may refer these quantity-related meanings to a single object. In this case, the operation that is typical of the quantitative modality (keeping the preceding items present as long as we add each new item) is still involved, but, instead of separate items, we consider parts that are considered conventional units (litres, kilos etc), or the extension of the attentional focalization. That is, in the latter case the operations are substantially the same as those of the categories “big” and “small”. This is in perfect agreement with the following two facts:

- 1) in several languages, such as English, we can find the same word in relationship to quantity (“a *little* water”) and the spatial extension (“a *little* room”);
- 2) in many languages, the words corresponding to “much” and “few”, besides being used in relationship with quantity, are (or can be) also used in relationship with the spatial extension (for example, the English sentence “I have gone a *long* way” is translated by the French sentence “j’ai fait beaucoup de chemin”, which literally means “I have made *much* way”) or the temporal extension (for example, the English sentence “I waited a *long* time” is translated by the Italian sentence “ho aspettato molto tempo”, which literally means “I waited *much* time”).

The only difference is probably that, when we consider space, *ad hoc* nervous structures are activated, as we stated. Nevertheless, when we consider something from the quantitative point of view, the operational modality is still the same, the one that we called “summative”, that is, keeping something present when we add something else of the same kind, whether separate objects which are distinct by themselves or portions of matter or parts of an ordered mental representation (that is, a “map”) related to a physical or non-physical *continuum*.

In many languages, the words corresponding to “much” and “few” are (or can be) also used with intensity (for example, the English sentence “it is very hot” is translated by the Italian sentence “é molto caldo”, which literally means “it is *much* hot”). Other languages use **more specific terms for intensity**, such the English word **very** (see “intensifier” in Wierzbicka’s list).

A range of intensities can surely be mirrored in a “map”. Nevertheless, it is more probable that a “map” is activated when we estimate an intensity by means of units of measurement (for example, when we are speaking of temperature in terms of degrees). In daily subjective estimates of intensities (for example, “it is very hot”) it is simpler to suppose that these words are directly related to the degree of the subjective sensation. The same also applies when the words “much”, “all” etc refer to non-physical things (“with *much* pleasure”, “with *all* my love” etc). Here too, there is an alternation between “much/few” and terms that are more often used in relationship with space, such as “big/small” (“with great/much pleasure”; this phenomenon varies across languages).

Naturally, the terms **more** and **less** indicate the two possible results that differ from equality, of the operation of comparison (C) that concerns quantitative estimates.

Verb-related Objects

We have stated that things that require a *prolonged* attentional focalization to be known are the meanings of the verbs (or words whose theme or root is of a verbal kind, such as “recognition”, “invasion”, “birth” etc). When we recognise what a verb designates, our attention can almost always also isolate some objects, which we recognise *instantaneously* instead, from the process or state (for the sake of simplicity, from now on we shall only use the word “process”) that is the meaning of the verb. The few cases where this does not happen are essentially the verbs that designate meteorological phenomena, such as “it rains”, “it snows” etc. In this case there is practically no instantaneously recognisable object that is separated from the process: all we see is the process only (for example, with the verb “to rain” there is practically no separate object (“water”), because when it rains water appears in a particular form, which is typical of “raining”, and this form cannot be separated from the process of “raining” itself). In all other cases instead, one or some instantaneously recognisable objects can be separated from the process designated by the verb (for example, in the case of the meaning of the verb “to fly”, there is always an object that can be separated from it and that can be recognised instantaneously, such as a bird). These objects have, with respect to the process and each other, *very precise relationships that are their role*. In other words, there is a temporal-causal *intrinsic order* in the process and the objects involved in it. Since in most cases all objects precede, as to *existence*, the process, and the situation is captured very quickly, the presence of such a temporal-causal order can escape at first sight. If we think carefully, we shall realize that, when *the dynamics* of the process are considered, such a temporal-causal order is always present and the attention *must* follow it. Let’s consider it in detail.

1) There is always an object that originates and carries out the process, that is, that *precedes and determines the progress of each phase* of the process. In other words, such an object that, if removed (mentally, that is, by means of an operation of representation [R], or physically too), the process would not exist (that is, the operational scheme is the same as that of causality, which we have already examined). Since such an object precedes each phase of the process, it is *necessarily* focused on *first* by the attention that follows the process, and kept present. The object with such features is the **agent**. Some languages have a particular mark to indicate the agent (for example, Japanese has the affix [ga]). Many other languages do not have a particular mark, but indicate this meaning by means of **the construction of the sentence** and the **active or passive form of the verb**. When the verb is in the active form, the agent is used as subject, therefore something that, as we have seen, is focused on by attention *before* the verb, thus *in the same position that the agent has in the process* (note that the active form of the verb is, in many languages, simply the verb without any mark or with more simple endings than the passive form, showing that this *is the natural order* of things). When the verb is in the passive form, the agent is indicated by a case mark or a preposition (“by” in English, but some other languages, as we have seen, use the preposition that corresponds to “from”, which indicates one of the two possible attentional movements with respect to something, moving away: this preposition is therefore very suitable to indicate *the origin* of an action). In this construction, the patient, i.e. what *comes after* in the natural temporal-causal order of the process (see point 4 below) is used as subject, that is, focused on *before* by attention (because we are paying more attention to it, see point 4 below). The fact that the passive form of the verb is, in many languages, the marked one or the one that has more

complex endings than the active form is a demonstration that this *is not the natural order* of the process. When the meaning “agent” is used as a substantive, many languages use suffixes, such as in English “-er”. Note that my analyses of “agent” and “subject” are *clearly different* from each other, in agreement with the clear-cut difference that has always been sensed between these two categories. In fact, we have proposed that the “subject” is what *is focused on by attention and kept present before a verb*, while the “agent” is what *precedes the verb from the temporal-causal point of view in the natural order of the process*.

2) There may also be a second object, which is almost always unanimated, *between* the agent and the process. This means that, in the dynamics, it follows the operating of the agent and, as the latter, precedes the process from the temporal-causal point of view. This second object is designated by the term **means**, when we indicate it in an isolated way, i.e. as a substantive. At the level of the correlational network it is indicated by the **instrumental case** or **equivalent prepositions** (in English, **by**) or prepositional phrases such as the English **by means of**. In many languages, instead of this correlator we can also find, as we have seen, prepositions that have a *more general operational scheme than the instrumental one, but which can include the latter* (in English, “with” [“to write with a pen”] or, less commonly, “through” [“he was hired through an agency”]). Naturally, it is this intermediate position of the object between agent and process that explains the English term “means” and the other analogous terms of many other languages.

3) The third element of the dynamics is the process itself. At this point, maybe there are no other objects in the dynamics of the process, and so the attention does not pass to something else. It is probably this *not passing or passing of the attention* to something else that unconsciously determined the grammatical terminology **transitive/intransitive verb**, not the fact that there is “an action that passes from subject to object”, as is usually said. This definition works in the many cases where the object exists before and is modified by the process designated by the verb (“to dig the ground”), but does not work in examples such as “to dig a hole” or “feeling pain”. Therefore, if we consider that what passes is the attention, the terminology “transitive/intransitive verbs” seems correct.

4) On the contrary, in following the dynamics of the process, the attention may *pass* to a third object, which *follows* the process *from the temporal (in the dynamics, not as to existence, as we said) and effectual point of view* (that is, this object receives an effect from, or is in effect of, the process). The effects can be many: existence (“building a house”), end of existence (“destroying a house”), modification (“folding a sheet”), movement (“moving the furniture”), etc. This object is what linguistics generally calls the **patient**. Like the agent, some languages have a particular mark to indicate the patient (for example, Japanese has the affix |o|), but many others do not have it. As mentioned in point 1, the latter indicate this meaning by means of a **construction of the sentence where the patient is the object** (indicated by the related mark or position) **and the verb has the active form**. There are some cases where the attention focuses on the patient more intensely (variation in intensity of the attentional focalization, AFint-var, which was mentioned when the EOMC were examined) than the agent, sometimes to the point that the latter can even not be expressed (“John has been wounded”). In many languages, this is expressed, as mentioned, by means of a **construction of the sentence where the patient is the subject, the verb has the passive form and the agent** (if expressed) **is indicated by a preposition or a case mark**. In some languages, such as Italian, the preposition used is the equivalent of the English preposition “from”. As mentioned, this preposition indicates one of the two possible directions of the

attentional shift with respect to something, the moving away ($A \rightarrow$). Therefore, this preposition is very suitable to designate the agent of a verb in the passive form, because, as we have seen, in the temporal-causal dynamics of the process the direction is agent $\rightarrow$ process.

5) Following the dynamics of the process may also imply *shifting* the focus of attention to a fourth object. This is the **indirect object**, which is expressed, depending on the language, by the dative case or the preposition “at/to”, which indicate, as we have seen, this shifting (English also uses word order, as we have seen).

As mentioned, it may be difficult realizing the temporal-causal dynamics that has just been described, because we perform these operations almost instantaneously, unconsciously, without any effort and many times a day. In order to realize them better, let's take a situation where all the aforesaid objects are present, such as the one described by the sentence

Mary Gave the Book to Paula by Her Own Hands

and try to slow down the action to capture what the intrinsic temporal-causal order of the process is. Although this may all seem simultaneous at first sight, and all the objects exist before the verb, a more careful reflection will show that, whatever the order of the sentence that a given language uses, “Mary” is always *before* the process *in its progression* and the attention focuses on her as such, *then* comes “her own hands” (which also *precedes* the process in its progression), *then* comes the process of “giving”, which *precedes* the “book” in the dynamics (this is very evident when the verb creates the patient, such as in the expression “to dig a hole”) and *finally* implies a shifting of the attention to “Paula”. This agrees perfectly with the fact that a construction with the agent as the subject, that is, in the first place in the descriptive thought (i.e. the active construction) is the standard construction.

Some Fundamental Verbs

We have stated that the object in point 4 of the preceding paragraph can *be the effect of*, or *receive an effect from*, the process. In both cases there is a *causal* relationship, that is, the representation of the absence of something, *A* (the cause), is followed by the representation of the absence of something else, *B* (the effect), as we saw. Yet, while in the second case the process has an effect on something *that already exists* (the existence of the object *precedes* the process), in the first case the process *determines the existence* of the object (that is, the existence of the object *follows* the process). The latter relationship can be in a *pure* form, i.e. without any other specification about the process or the object. This is the meaning of the verb **to make** (Wierzbicka's list includes the English verb “to do”, which differs from “to make” more as to use than as meaning; in fact, other languages have only one verb). This analysis can be verified by examining the examples provided by dictionaries, which show that the existence of the object of the verb “to make” is always determined by the process that is designated by the verb itself (for example, “to make: a son, a noise, a law, a cake, a face, money, troubles, friends, someone laugh, something better, sure, clear etc). Furthermore, if we try to think of the meaning of the verb “to make” in an isolated manner, we should sense that the meaning of this verb lies exclusively in this coming into being of the object as a consequence of the process. The close relationship of the verb “to make” with a typical form

of causation, i.e. the causation of existence, is supported by: a) the more or less evident etymological relationship that exists in many languages between the term “effect” and the verb “to make” (in English the relationship is with the verb “to do”, which derives from the Indo-European root *DHĒ*, from which we also have the Latin verb *facere*, from which “effect” derives in turn); b) the fact that dictionaries explicitly call the use of this verb “causative” when, as often happens, it has another verb as its object (which can be any verb), such as in the expression “to make laugh” (the meaning of the verb is obviously the same here, but the thing that the process of “making” determines the existence of is another process, instead of a substantival meaning, such as in the expression “to make a cake”). Therefore, the meaning of the verb “to make” is the most general of all the verbs for which the aforesaid scheme “process → existence of the object” is valid. This clearly explains the following two facts: a) this verb is or can be used in innumerable cases; b) it is used in questions where we want the listener to answer as freely as possible (“What are you doing?” [for the difference between “make” and “do” in English, see above]).

The verb “to hold” is included in the Swadesh list, where “to have” is missing. Actually, the meanings of the two verbs are similar. The verb **to hold** and, even more so, the verb **to keep** (this distinction is present in English, but other languages have a single verb) indicate the same relationship as “to have”, but also the agent-process relationship that we saw in the previous paragraph, in point 1. That is, the persistence of such a relationship between two objects that our attention tends to focus on both objects together (i.e. the meaning of “to have”) is caused by an agent. One should sense this difference between “to have” and “to hold/keep” very well by comparing the two pairs of expressions “she has/holds a baby in her arms” and “he has/keeps the engine on”: both in the first and the second pairs of expressions the (static) relationship is the same (there is a closeness between a baby and a woman’s arms, and a running engine and someone, respectively), but when “to have” is used, the fact that the baby remains in the woman’s arms and the engine remains on, does not depend on the activity of the subject, whereas in the other two cases it does.

Let’s examine the verb “to be”. In English, this verb is generally said to have two (only two) meanings.

- 1) An example of the first meaning is “the book is on the table”. In this meaning, in English (as in many other languages) the verb is often used together with a particle having a locative meaning (“on the table *there* is a book”). Since this meaning seems similar to that of the verb “to exist”, it is often referred to as the “existential meaning”.
- 2) The second meaning is commonly called “copula”, which is used very frequently and for which there are infinite examples (“the book is nice”, “the sky is blue” etc).

In many languages there is the same situation as in English. Other languages have two distinct verbs to express meanings 1 and 2, or express the copula in a different way.

In addition to being used alone, the verb “to be” is also used in many languages as an auxiliary verb (for the passive conjugation and some tenses of the active conjugation), which makes it the most used verb.

Let’s attempt to identify the aforesaid meanings in terms of EOMC. We have stated that all verbs indicate a temporal operational scheme (TOS), that is, the attention follows the evolution of something over time. The verb **to be, in the existential meaning**, designates the

simplest thing a verb can designate (in fact, grammarians have always sensed that “to be” is the most elemental of the verbs), i.e. something is, or can be, focused on by attention and this persists over time. That is, if we simply realise that, for a certain time (which will be indicated by the tense of the verb “to be”), something is, or can be, focused on by our attention, we say exactly that such a thing “is”, or “there is”, or “exists”. For example, “the book is on the table” means that, at the present time, “the book” is (or we know it can be) focused on by attention “on the table”.

Instead of focusing our attention on *only one thing*, *A*, and seeing that *A* persists over time, we can also focus the attention on *something*, *A*, and a *feature of it*, *B*, and have the same result. This is the **copulative meaning of the verb to be** (for example, “the book is red”). The fact that *B* is a feature of *A* implies that *B* is an adjectival meaning (as in the example that has just been made), or a substantival meaning that is yet used as an adjective, such as in the expression “John is an engineer”: what matters is that *A* and *B* are not separate, but fused in *the same* attention focalization. Therefore, since there is little difference between the existential meaning and the copulative meaning of the verb “to be”, it is natural that many languages use the same verb in both cases. It is also natural that, as mentioned, many languages use “to be” as an auxiliary verb, in order to express the passive form of all other verbs. The verb “to be”, in this copulative function together with a verbal form that has an adjectival and passive meaning, such as a past participle (for example, “the thief *is arrested* by the police”) lends itself perfectly to this purpose. This allows a noticeable morphological simplification in comparison with languages such as Latin and ancient Greek that have a large series of endings (those to express the person, tense, mood etc) specifically for the passive form.

The operational structure provided here for the meaning of the verb “to be” in its copulative meaning is partly similar to the structure of the verb “to have”. We have stated that:

- “to be” in its copulative meaning designates focusing on something and a feature of it and seeing all of this persisting over time;
- “to have” designates (as does the preposition “with”) the fact that two distinct objects, *A* and *B*, are in such a relationship that our attention, when focusing on *A*, tends to include *B* in the same focalization as well.

In both cases there is a relationship between two items that persists over time. Therefore, the only difference between the two verbs is that:

- a) the nominal predicate of the verb “to be” in the copulative function is given by:
 - an adjectival meaning, which, as stated, is a feature of something else (for example, “the sky is blue”), or
 - a substantival meaning that has the same value, because it *coincides* (that is, it is the result of the same attentional focalization) with the subject (for example, “John is an engineer”);
- b) the object of the verb “to have” is a meaning of a substantival kind (something that is, or is considered to be, independent) that *does not coincide* with the subject, i.e. is

not the result of the same attentional focalization (for example, “John has blonde hair”).

This analogy and this difference between “to have” and “to be” in its copulative meaning clearly explain the fact that if we substitute an adjectival meaning with the corresponding substantival meaning, it is generally possible to pass from an expression with “to be” to another expression with “to have” (or the preposition “with”) that has the same meaning, and vice versa (for example, “man who *is* rich/who *has* much money/*with* much money”).

My analysis for the existential meaning of the verb “to be” explains the fact that in some languages the meaning of the verb “to have” is, or can be, expressed by means of the construction of the sentence *object of ‘to have’ as subject + verb ‘to be’ + subject of ‘to have’ in the dative* (for example, in Latin: *mihi est spes* = “I have a hope”, literally “to me is hope”). In fact, the meaning of “to have” (two distinct objects, *A* and *B*, are in such a relationship that our attention, when focusing on *A*, tends to include *B* in the same focalization as well), can be also expressed by saying that *B* has to be referred to *A*. This fact implies a shifting of the focus of the attention, which is typical of the dative, as we have seen.

This similarity between the verbs “to have” and “to be”, and the fact that, as suggested, the preposition “with” and the verbs “to have”, “to get” and “to hold/keep” are based on the same operational scheme, offers a very good explanation of the phenomena of mutual substitution amongst these terms, which are found across languages. In cases where a language uses the preposition “with”, another language may use the present participle of the verb “to have”; instead of the verb “to have” we may find the verb “to be” together with the preposition “with”, or the aforesaid construction *object of ‘to have’ as subject + verb ‘to be’ + subject of ‘to have’ in the dative case*; or, instead of the present of the verb “to have” some past tense of the verb “to get”; etc. Our intuition tells us, for example, that in the following pairs of expressions (the second expression in each pair is a literal translation of the expression found in other languages [in italics], or what can be found in English itself):

- man with a stick/man having a stick
- to have a temperature/to be with a temperature
- I have a book/a book is to me
- I have/I have got

the two expressions of each pair are equivalent, but the hypothesis that the operational schemes which make up the meanings of these terms have the similarities that have just been described is a far more satisfactory explanation.

Modal Verbs

The main so-called “modal verbs” are “to want”, “can/may” and “have to”. For the time being, only the last two will be examined. Unlike “to want”, which can also govern a substantive (“I want an ice-cream”), “can/may” and “have to” always govern another verb. Therefore, it can be said that these two verbs add some meaning to the meaning of the verb they govern. The first observation to make in order to identify their meaning is that, when one

of these two modal verbs is used, the process or state (the word “process” will be used from now on) that is designated by the governed verb cannot have taken place at the time indicated by the tense of the modal verb. Saying “I can/have to work” makes no sense if we have already worked (at the most, we may say this if the action is still taking place, i.e. is not finished). In fact, the time when the process that is designated by the governed verb happens is generally in the future with respect to the tense of the modal verb. Sometimes, the tense can be the same or in the past tense (for example, in the sentence “dinosaurs may/must have become extinct because of the impact of a meteorite”), but in these cases the process, even if it refers to the past, it is not considered to have happened, because we do not know if it happened. If we knew it happened, these verbs could not be used. All this is because “can/may” and “have to” concern the *carrying out/reality* of what the governed verbs designate (I use the expression “carrying out/reality” because in some cases the former is involved, in others the latter: for example, “today I must/can work” and “there must/may be a solution”, respectively). More specifically, they designate an operation of representation, *which is based on something real*, regarding the carrying out/reality of what the governed verb designates. That is, first we *represent* (R) the meaning of the verb that is governed, which is not, at the moment, *real/a known reality*, then we represent *its carrying out/reality*, basing ourselves on another element (there is no need to say how important this is in practice). In this carrying out/reality, the following two cases are possible.

1) *There is no alternative*, i.e. the aforesaid operation of representation produces a *single* result: verb **have to** (for example, “I have to go out” means that something induces the representation of carrying out the action of “going out” only). The element which the representation is based on can be a material circumstance, a moral rule etc and the intensity of its power to condition can vary. Therefore, several languages use different verbs for the various cases (for example, the English verbs “must”, “have to”, “shall”, “should”, “ought to”).

2) *There is an alternative*, i.e. the aforesaid operation of representation produces a *double* result: verb **can/may** (for example, “I can/may go out” means that something induces the representation of performing or not performing the action of “going out”). The element which the representation is based on can be a material circumstance, can depend on the subject or somebody/something other than the subject, or can be an unknown factor (eventuality). Therefore, several languages use different verbs in these different cases (for example, English uses “can” in the first two cases and prefers “may” in the latter two), while other languages, such as Latin, generally use only one verb and rely on the context to understand what determines the fact that we “can/may”. The case of eventuality is also expressed by means of the adverb **maybe** (see Wierzbicka’s list) or phrases such as “it is possible that”.

Instead of saying that the two verbs “can/may” and “have to” designate the presence or the absence of an alternative, respectively, it is perhaps more exact to say that “have to” indicates that there is no alternative *to the* carrying out/reality (that is, the carrying out/reality is sensed as the first pole of an alternative that lacks the second pole), while “can/may” indicates that there is *the* alternative *of the* carrying out/reality (that is, we have the alternative of performing/not performing the action).

My analysis clearly explains why the negation of the verb “can” that refers to the negation of the governed verb (that is, “cannot not”) is equivalent to “must”: if the alternative of the negation is excluded, we obtain the absence of an alternative.

Based on the above, the meaning of these two verbs typically has two components:

- 1) *the basis of the representation* of the carrying out/reality of the meaning of the governed verb, which will become the reason or cause of the fact that we “can/have to”;
- 2) *the representation itself* of the carrying out/reality.

The presence of these two components, and the fact that the second is based on the first, clearly make “have to” and “can/may” different from the simple representation of the future. In fact, when we use these verbs, we are, or we place ourselves mentally, in the time that they designate, where there is the element that conditions the process that the governed verb designates, an element that is *a fundamental integral part* of the meaning of these two verbs. Nevertheless, basing ourselves on this element, we perform an operation of representation of a carrying out/reality, which often refers to the future. Moreover, in the case of the verb “have to”, the result of this operation is only one, therefore equal to the operation that makes up the future tense (which corresponds to the fact, which everybody senses very well, that, if “we must do”, the result is often that “we shall do”). This explains why in some languages the formation of the future tense of verbs has a relationship with the verb “have to”, which is evident (such as in the first person of the English future tense) or etymological (such as in most Romance languages, where the morphology of the future tense derives from the Latin verb *habeo*, “to have”, in the sense of “having to”: for example, the Italian future tense *farò*, “I shall make” derives from the Latin expression *facere habeo*, “I have to make”).

We shall also mention the verb **to want** here because it is commonly considered a modal verb, i.e. a verb that modifies other verbs. Nevertheless, the analogy with “can/may” and “have to” stops here, in my opinion. I have already pointed out that “to want” is clearly different from the two former verbs, because it accepts (and often has) not a verb, but a substantive as its object.

At the level of meaning also, there does not appear to be any analogy with the operations that the two other modal verbs are thought to designate. On the contrary, in my opinion there is no way to account for this meaning with the operations within cognitive functions (attention, memory etc) that I have used to account for the meanings that we have considered up to now. In my opinion, “to want” designates a specific function, *will*, which is *a function apart*, and completely different from the aforesaid functions. In fact, *will* has been repeatedly considered as such, more or less explicitly, in philosophy, psychology, cognitive psychology and psychiatry.

In my opinion, *will* should be considered a psychic function rather than a mental one, even if it seems intrinsically related to one of the operations considered, that is, the representation (of its object), because it seems that we cannot want something, at least consciously, without representing that something. All I can say about *will* is that it seems a “stimulus”, inside the psyche itself, to the carrying out or achievement of a representation (R). A feature of this function is that it varies in intensity, so that languages generally have different terms to express different degrees of its intensity (for example, “to want” and “to wish”, in English). The **imperative mood of the verb** is closely related to this function. This mood expresses the will of the speaker that a subject, other than the speaker himself, carries out a representation (R) of a verbal phrase that the speaker tells the listener.

The Interrogative Sentence

Let's examine the meaning expressed by the term **question** (as a substantive) and **the interrogative form of the sentence** (a particular construction or tone or verbal mood or particle or more than one of the former, depending on the language). There are three kinds of questions.

- 1) Those introduced by the pronouns/adjectives "who", "what", "which", "where", "when", "how". As we have seen, all these terms designate an unsolved *alternative*.
- 2) Those not introduced by the aforesaid pronouns or adjectives, but where *an alternative* is indicated explicitly (for example, "Are you leaving or staying?").
- 3) Those where *an alternative* is not indicated explicitly, but is clearly present (for example, "Are you leaving?").

Therefore, we can say that an alternative is always present in a question. It is an alternative in the representation. That is, the operation of representation produces an alternative as its result. The alternative can be given by:

- a) two terms that are both indicated explicitly (case 2), or
- b) two terms of which only one is explicitly indicated, while the other, which is implicit, is the negation of the first (case 3), or
- c) a term whose meaning is exactly an unsolved alternative, that is, selecting one item of a group of items that are equal to each other (this is the basic meaning of the terms in point 1, as we have seen).

The question is the mental operation of the search for the solution of the aforesaid alternative, that is, searching which term of the alternative to accept while discarding the other/s. We keep the alternative in the representation (R) present (PK) while, by means of attention, we look for something in reality that allows us to choose one of the terms of the alternative. This is generally done by resorting to the knowledge of other people, because, if the solution is present inside our knowledge, it is often immediately available and therefore the search for it is so quick that even we are not aware of it. Nevertheless, we sense very well that sometimes we ask questions to ourselves too, when the aforesaid solution is not immediately available (for example, "I ask myself how he did").

9. RELATIONSHIPS BETWEEN OS AND OTHER APPROACHES TO THE STUDY OF COGNITIVE ACTIVITY

As we can understand very well from what has been said up to now, OS lies somewhere between cognitive psychology and linguistics. Actual or possible relationships between OS and psycholinguistics (and the related neurolinguistics) can surely be found (even if OS has an independent origin, as we said). We cannot deal in depth with this subject in this chapter, which aims to provide a general introduction. Here, we can only mention very briefly the main actual or possible relationships.

1) A central question in psycholinguistics is how human beings manage to create syntactic sentences, that is, whether syntax is an evolutionary product of increased human intelligence over time and social factors that encouraged the development of spoken language, or language exists because humans possess an innate ability, an access to what has been called a “universal grammar” (the first view is well represented by the mentalistic theories of J. Piaget, the empiricism of R. Carnap etc; the second point of view can be said to have begun with N. Chomsky [Chomsky 1959]). With regard to this, OS’s position is an intermediate one. In fact, in my opinion, it is *only the ability of carrying out the EOMC that is innate*. On the contrary, *the ability of making up mental categories by means of these operations*, and of building the structure of thought by means of the mental categories, *is acquired* and culturally transferred, from generation to generation. The fact that in the various languages most of the mental categories are common (so that translation is always substantially possible) derives from the fact that humans live in physical environments that have a lot of similarities and have more or less the same necessities in communication. Sometimes these necessities can nevertheless be satisfied in different ways, with the result that in the various languages there can be some differences both amongst the various mental categories and the structures of thought that are used. For example, in English there is no word with the same meaning as the Italian demonstrative adjective/pronoun “*codesto*”, which designates a distance from the one who speaks and a closeness to the one who listens (in English, we can only indicate either a distance from, or a closeness to, the one who speaks). All of this is in agreement with both the fact that the so-called “linguistic universals” [Lehmann 1992; Comrie 1989] are really very few and with the well-known fact that the so-called “feral children” lack language. We can clarify the position of OS about the innate component of thought/language and the cultural one by means of a simple comparison between language and the way of eating. There are some peoples who use knife, fork and spoon in order to eat, some who use sticks, and others who use (or used) their hands. These customs are acquired and culturally transferred, and differ from each other (in the same way as the syntax and some mental categories of the various languages can differ from each other). Nevertheless the gesture of using your hand to put food into your mouth is common to all humans (in the same way as most of the syntax and mental categories are common to the various languages), because the fact that humans have arms, hands and a mouth, which are in a certain reciprocal position, is genetically determined (in the same way as the ability of carrying out the EOMC is genetically determined) and the fact that we have to put food into our mouth is a common necessity (in the same way as what humans have to communicate is largely common).

2) Psycholinguistics also deals with the comparison between human language and animal communication (for OS’s position with regard to this, see above, p 25) and with research into the possibility of a partial learning of human language by animals. S.O.I.’s theoretical approach has also been applied to the latter problem. In fact, within the Lana Project (USA, 70’s), research into the possibility of linguistic communication between man and animal (the animal was a female chimpanzee, named Lana), a S.O.I. member, E. von Glasersfeld, created an artificial language based on Ceccato’s theories. This language (which comprised some mental categories) allowed the chimpanzee to show her having acquired such mental abilities to produce sentences, which were grammatically correct and had a sense, even if they were very simple [Glasersfeld 1989].

3) As regards the application of psycholinguistic methods to OS, the eye tracking method, used in psycholinguistics to study the cognitive processes related to spoken language [Tanenhaus, Spivey-Knowlton, Eberhard, Sedivy 1995], was also used by Ceccato as early as the 60's. We may hypothesize that the methods of experimental cognitive psychology and cognitive neuroscience could also be used to verify the hypotheses about the mental categories formulated in this chapter. For instance, it can be hypothesized that during the production of the mental categories considered in this chapter, brain areas involved in selective attention, divided attention or memory (shown by means of techniques such as fMRI, PET, EEG etc) are differently involved somehow according to the analyses proposed here.

Recently, An. and Al. Fingelkurts have put forward the hypothesis that there can be a correspondence between the theory of brain-mind functioning they propose, called *Operational Architectonics* (OA; Fingelkurts & Fingelkurts, 2001, 2003, 2004, 2005, 2006), and OS. OA, which was developed starting from Kaplan's work [Kaplan et al., 1995; Kaplan, 1998, 1999], is an innovative neurobiological theory founded on the joint analysis of cognitive and electromagnetic data (EEG and MEG) and based, similarly to OS, on the central notion of "operation". According to OA, every conscious phenomenon is brought to existence by the joint operations of functional transient (synchronised) assemblies of neurons, called Operational Modules (OM). Experiments have been suggested to verify the putative correspondence between the theoretical frameworks of OA and OS [Benedetti, Marchetti, Fingelkurts, and Fingelkurts 2009].

As a conclusion, we may say that OS is a general theory concerning linguistic thought and language, and here it is introduced as such. The methods used by psycholinguistics could also be applied to OS. Relationships can be found and comparisons can be made between OS and psycholinguistics (and other approaches). However, the complexity of the subject cannot be adequately dealt with in such a propedeutical chapter as this.

10. THE LIMITS OF OPERATIONAL SEMANTICS

Even if the theories I have introduced are, at least as outlined in general, correct, we should nevertheless note that OS allows us to understand the nature and structure of the processes of thought and language *only partially* and *only up to a certain level of "depth"*. In fact, even if it is possible to identify the meaning of the mental categories, it is instead impossible to go *beyond* this level. In fact, OS defines, or describes, the meanings of the aforesaid linguistic elements in terms of operations of attention, memory etc, but it cannot tell us how these functions are carried out and what supports them.

Moreover, OS allows us only to "see" what we may call, to use a metaphor, the "bare skeleton" of thought and language, that is, the mental operations we perform on, and that are elicited by, *our subjective phenomenal experience*. That is, to make an example, if we consider the expression "the colours of flowers", OS can only account for the meaning of the word "of" and the morpheme "-s", but not the words "colour" and "flower". We have said that the words with an evident and important reference to something physical are one of the two fundamental components of human language. In my opinion, we should rather say that this component is given by words that designate *our subjective phenomenal experiences* (the

so-called “qualia”, or components of “phenomenal consciousness”), *which the physical world somehow elicits inside us, and which we “project” outside our mind, identifying them exactly with the physical world.* Apart from the inferences of science, our subjective phenomenal experience is *the only thing* that puts us into relationship with the physical world. Therefore, our subjective phenomenal experience is so usual for us that we are led to identify it with the physical world. That is, we are led to believe that “there, outside us” there are light, colours, sounds, etc. In my opinion, it is absolutely not so. “There, outside us” are electromagnetic waves, mechanical vibrations, etc, which *invariably make us feel* the sensations of light, colour, sound, etc, but which *are not* these sensations. The sensations *exist only inside us* (for a similar view, see Revonsuo, 2006). This is not evident because, as we have said, our phenomenal experience is the only, therefore usual, direct intermediary with the physical world; and because, for each of most of the various kinds of sensations, there is only one external stimulus that can produce it (that is, only electromagnetic radiation gives us the sensation of light and colour, mechanical vibrations give us the sensation of sound, etc). But for some kind of sensations it is not so. For instance, there is no specific external stimulus for the sensation of pain. In other words, “there, outside us”, there is no “pain”: there are only various physical events that, by means of the physical mechanism of cell lesion with the emission of potassium ions, etc, *make us feel* the sensation of “pain” (in a completely unknown way), but that *are absolutely not* “pain” (nor is cell lesion “pain”). It is the same for any other sensation. The only difference is that for most kinds of sensations there is, almost always, stimulus specificity (the few exceptions are the well-known phenomena such as the strong compression of the eyeball, which elicits a sensation of light, etc).

Thus, *a fundamental part of our thought*, which is designated by language (that is, a fundamental part of the general problem of Semantics, i.e., “what does language designate?”) *is exactly our subjective phenomenal experience.* OS cannot tell us anything about this (for a different opinion, starting from the presuppositions of OS, see Marchetti 2006).

11. POSSIBLE PRACTICAL APPLICATIONS OF OS: IMPLEMENTATION OF A MACHINE TRANSLATION PROGRAM OF A NEW KIND

The correlational theory of thought has allowed the conception of a device for the implementation of a machine translation¹⁷ program, which should allow us to achieve a noticeably better translation quality than that of the programs available today, especially when the source language is a language with very little morphology and a lot of ambiguities, such as English, and the target language is a language with rich or very rich morphology (such as French, Spanish, Italian, German, Russian, etc). This device is described in detail in Benedetti 2005d¹⁸. What the program should allow us to achieve is not a *good* translation, but what the programs available today do not guarantee, that is, an output text which is generally *understandable and without big distortions*, so that the user who does not understand a certain

¹⁷ The references for the history and the state-of-the-art of machine translation are: Hutchins 1986, 1992, 1999, 2001a,b, 2002, 2003.

¹⁸ This device was conceived by Ceccato and his collaborators in this project (Ceccato 1969; Glasersfeld, Pisani 1970). Only minor modifications and the description, which is rather different from the original one, are my own.

language can understand a text written in that language. The characteristics, which make this program different from all others, are the following.

- 1) The device is based on the correlational theory of thought, which is, as we saw, a radically new and deeply different linguistic theory from the other linguistic theories.
- 2) Basing itself on this theory, the program simulates, even if does not reproduce, a part of what the human beings actually do by using their intelligence when they translate, that is, rebuilding the structure of thought that corresponds to speech and choosing the meaning of a word (when a word may have more than one meaning) according to the sense of the sentence. In this way, the main problem that machine translation has always had, that is, the fact that the programs do not understand what they have to translate, is tackled and, in a wide part, solved at its root (even if thanks to an artifice).
- 3) The device is the only one that is completely and exclusively based on a single linguistic theory.
- 4) The device is the only one that is conceived by the persons who proposed the linguistic theory which the device itself is based on.
- 5) The number of ways in which the words making up a sentence can combine according to the correlational theory of thought is a finite number and not particularly high (it can be mathematically calculated starting from the number of words in the sentence and the number of the explicit correlators present in it). The program generates all the possible combinations (in order to examine them later), therefore the right combination is also surely produced.

The program does not seem particularly difficult to implement from the theoretical point of view and does not require any special hardware or software technology. Therefore, this program could be implemented even now. The only problem that the implementation of this program presents is the fact that the human work needed to construct the extremely complex “notional spheres” the program is provided with (these notional spheres allows us to simulate the translation of the human being as described in 2) increases exponentially as the number of dictionary entries increases. Therefore, this is not a theoretical but a practical problem. Nevertheless, a first level experimentation in order to verify the validity of the program is, on the contrary, rather simple. We can start by providing the program with a very small dictionary, a dictionary of a few dozen words. Even with so few words we can build a large number of sentences and can check that the program does not make the kind of errors that are commonly found with current programs.

CONCLUSION

In this chapter, the author has stressed the fact that words and morphemes seem divisible, as far as the nature of their meaning is concerned, in at least two main classes: 1) elements that seem to make an evident and specific reference to something physical; 2) elements that do not seem to refer (or refer only) to something physical. Class 2 consists mainly of the words that we may call “grammatical” (prepositions, conjunctions, interrogative-indefinite-

relative pronouns or adjectives, demonstrative adjectives and pronouns, main adverbs of place, time, manner etc, pronouns/adjectives of quantity, numerals, negation, fundamental verbs like “to be”, “to have”, etc) and of most morphemes of the large number of languages that have a more or less rich morphology. The elements of class 2, even if they are much less numerous than those of the first class, are almost always, as a class, the main component of any speech and seem absolutely indispensable in order to speak. Therefore, it seems possible to affirm that until we have understood the *nature of the meaning* of these words and morphemes we shall not understand the nature of a fundamental component of thought and language. In this chapter the author has tackled the problem of the semantics of these linguistic elements, introducing a radically new theory (Operational Semantics) about the nature of their meaning and of thought-language in general. This theory is based on the fundamental assumption that the meanings of these linguistic elements are sequences of operations within cognitive functions, amongst which attention plays a key role. The author has shown that, basing ourselves on this assumption, it is possible to account for these meanings.

ACKNOWLEDGMENTS

I am grateful to Giorgio Marchetti, for his assistance in preparing this chapter; I am also grateful to Alexander A. and Andrew A. Fingelkurts, collaborating with them helped me outlining this paper. The English has been kindly revised by Mrs Wendy Piemonte.

REFERENCES

- Amietta, P. L. & Magnani, S. (1998). *Dal gesto al pensiero*. Milano: Franco Angeli.
- Baars, B. J. (1988). *A cognitive theory of consciousness*. Cambridge: Cambridge University Press.
- Baddeley, A. D. & Hitch, G. J. (1974). Working memory. In: Bower GA (ed) *Recent advances in learning and motivation vol. 8*, pp 47-90. New York: Academic Press.
- Baddeley, A. D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences* 4, 417-423.
- Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences*, 22, 577-660.
- Benedetti, G. (1999). La categoria di “spazio”, and Tavole sinottiche delle analisi di categorie mentali tratte dalle opere di S. Ceccato. In: F., Accame, E., Glasersfeld, von, V., Somenzi, R., Beltrame, M., Panetta, C. E., Menga, G., Benedetti, *Studi in memoria di Silvio Ceccato*. Roma: Società Stampa Sportiva.
- Benedetti, G. (2004). *Semantica operativa*. www.mind-consciousness-language.com
- Benedetti, G. (2005a). A presentation of Operational Methodology. www.mind-consciousness-language.com.
- Benedetti, G. (2005b). Basic mental operations which make up mental categories. www.mind-consciousness-language.com

- Benedetti, G. (2005c). On Giorgio Marchetti's commentary on my book "*Semantica Operativa*" [*Operational Semantics*], vol. I, 2004. www.mind-consciousness-language.com.
- Benedetti, G. (2005d). A device in order to improve the quality of machine translation, based on the correlational theory of thought. www.mind-consciousness-language.com
- Benedetti, G. (2006). Operational Nology as a new methodology for the study of thought and language: theoretical aspects and possible practical applications. *Cognitive Processing*, 7, 217-243.
- Benedetti, G., Marchetti G., Fingelkurts Al. A., Fingelkurts An. A. (forthcoming) Mind Operational Semantics and Brain Operational Architectonics: a Putative Correspondence.
- Benjafeld, J. G. (1997). *Cognition*. Englewood Cliffs: Prentice-Hall International.
- Bieri, P. (1992). Was macht Bewußtsein zu einem Rätsel. *Spektrum der Wissenschaft Okt.* 1992,48-56.
- Bloomfield, L. (1933). *Language*. New York: Holt, Rinehart & Winston.
- Braga-Illa, F. (ed) (1997). *Livelli di rappresentazione. Percorsi tra il naturale e l'artificiale*. Urbino: QuattroVenti.
- Braga-Illa, F. (ed) (2006). A proposito di rappresentazioni. *Alla ricerca del senso perduto*. Bologna: Pendragon.
- Chalmers, D. J. (1996). *The conscious mind. In search of a fundamental theory*. New York: Oxford University Press.
- Ceccato, S. (1964). *Un tecnico fra i filosofi vol. I, Come filosofare*. Padova: Marsilio Editori.
- Ceccato, S. (1966). *Un tecnico fra i filosofi vol. II, Come non filosofare*. Padova: Marsilio Editori.
- Ceccato, S. (1968). *Cibernetica per tutti, 1*. Milano: Feltrinelli (edited by Barosso G.).
- Ceccato, S. (ed) (1969). *Corso di linguistica operativa*. Milano: Longanesi.
- Ceccato, S. (1970). *Cibernetica per tutti, 2*. Milano: Feltrinelli (edited by Giuliani M.V., Zonta B)
- Ceccato, S. (1972). *La mente vista da un cibernetico*. Torino: ERI.
- Ceccato, S. (1974). *La terza cibernetica*. Milano: Feltrinelli (edited by Zonta B.).
- Ceccato, S. (1996). *C'era una volta la filosofia*. Milano: Spirali.
- Ceccato, S. & Oliva, C. (1988). *Il linguista inverosimile*. Milano: Mursia.
- Ceccato, S. & Zonta B. (1980). *Linguaggio consapevolezza pensiero*. Milano: Feltrinelli.
- Chomsky, N. (1959). A review of B. F. Skinner's Verbal Behavior. *Language* 35(1), 26-58.
- Chomsky, N. (1987). Language in a psychological setting. *Sophia Linguistica* 22, 1-73.
- Churchland, P. S. & Sejnowski T. J. (1992). *The computational brain*. Cambridge MA: MIT Press.
- Comrie, B. (1989). *Language universals and linguistic typology*. Chicago: The University of Chicago Press.
- Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, 24, 87-185.
- Cowan, N. (2005). *Working memory capacity*. New York, NY: Psychology Press.
- Damasio, A. R. (1994). *Descartes' Error, emotions, reason and the human brain*, New York: Grosset/Putman.
- Dehaene, S. (2005) Le basi biologiche dell'aritmetica elementare. *Le Scienze* 443 (7), 49-54.
- Denis, M. (1989). *Image et cognition*. Paris : Presses Universitaires de France.
- Dennett, D. C. (1991). *Consciousness explained*, Boston: Little Brown.

- Dryer, M. S. (2005). Order of subject, object, and verb. In: *The World Atlas of Language Structures*, edited by M. Haspelmath, M. S., Dryer, D., Gil, & B., Comrie. Oxford: Oxford University Press.
- Edelman, G. M. (1989). *The remembered present: a biological theory of consciousness*. New York: Basic Books.
- Edelman, G. M. (1992). Bright air, brilliant fire. *On the matter of the mind*. New York: Basic Books.
- Fingelkurts, An. A. & Fingelkurts, Al. A. (2001). Operational architectonics of the human brain biopotential field: Towards solving the mind-brain problem. *Brain and Mind.*, 2, 261-296.
- Fingelkurts, An. A. & Fingelkurts, Al. A. (2003). Operational architectonics of perception and cognition: A principle of self-organized metastable brain states. VI Parmenides workshop – Perception and thinking, Institute of Medical Psychology. April 5-10, Elba/Italy (invited full-text contribution). URL = <http://www.bm-science.com/team/art24.pdf>.
- Fingelkurts, An. A. & Fingelkurts, Al. A. (2004). Making complexity simpler: Multivariability and metastability in the Brain. *The International Journal of Neuroscience.*, 114, 843-862.
- Fingelkurts, An. A. & Fingelkurts, Al. A. (2005). Mapping of Brain Operational Architectonics. In F. J. Chen (Ed.), *Focus on Brain Mapping Research* (59-98). Nova Science Publishers, Inc.
- Fingelkurts, An. A. & Fingelkurts, Al. A. (2006). Timing in cognition and EEG brain dynamics: discreteness versus continuity. *Cognitive Processing.*, 7, 135-162.
- Glaserfeld, E. von & Pisani P. P. (1970). The multistore parser for hierarchical syntactic structures. *Communications of the ACM* 13(2), 74-82.
- Glaserfeld, E. von (1989). *Linguaggio e comunicazione nel costruttivismo radicale*. Milano: Cooperativa Libreria Universitaria del Politecnico.
- Glaserfeld, E. von (1998). *Il costruttivismo radicale*. Roma: Società Stampa Sportiva.
- Goddard, C. (1998). Bad arguments against semantic primitives. *Theoretical Linguistics* 24(2/3), 129-156.
- Goddard, C. (2001). Conceptual primes in early language development. In Putz, Martin, Niemeier, Susanne, & Dirven, Rene (eds.). *Applied Cognitive Linguistics I: Theory and Language Acquisition*. Berlin: Mouton de Gruyter, 193-227.
- Goddard, C. (2002). The search for the shared semantic core of all languages. In Goddard & Wierzbicka (eds.) *Meaning and Universal Grammar - Theory and Empirical Findings volume 1*, 5-40, Amsterdam/Philadelphia: John Benjamins.
- Goddard, C. & Wierzbicka, A. (eds.) (1994). *Semantic and Lexical Universals - Theory and Empirical Findings*. Amsterdam/Philadelphia: John Benjamins.
- Goddard, C. & Wierzbicka, A. (eds.). (2002). *Meaning and Universal Grammar - Theory and Empirical Findings (2 volumes)*., Amsterdam/Philadelphia: John Benjamins.
- Graffi, G. & Scalise, S. (2002). *Le lingue e il linguaggio.*, Bologna: Il Mulino.
- Hutchins, W. J. (1986). *Machine translation: past, present, future.*, Chichester: Ellis Horwood Series in Computers and their Applications.
- Hutchins, W. J. & Somers H. L. (1992). *An introduction to machine translation.*, London: Academic Press.

- Hutchins, W. J. (1999). *Retrospect and prospect in computer-based translation.*, Machine Translation Summit VII, 13th-17th September 1999, Kent Ridge Digital Labs, Singapore. Proceedings of MT Summit VII "MT in the great translation era". Asia-Pacific Association for Machine Translation, Tokyo, pp 30-34.
- Hutchins, W. J. (2001a). *Towards a new vision for MT.* Introductory speech at the 'MT Summit VIII' conference. Santiago de Compostela, Galicia, Spain.
- Hutchins, W. J. (2001b). Machine translation and human translation: in competition or in complementation? *International Journal of Translation* 13(1-2), 5-20. Also in: Blekhman MS (ed) *Machine translation theory & practice.* Bahri Publications, New Delhi.
- Hutchins, W. J. (2002). Machine translation today and tomorrow. In: Willée G, Schröder B, Schmitz H-C (eds) *Computerlinguistik: was geht, was kommt? Festschrift für Winfried Lenders.* Gardez! Verlag, Sankt Augustin, pp 159-162
- Hutchins, W. J. (2003). *Has machine translation improved?* Proceedings of the Ninth Machine Translation Summit. AMTA, East Stroudsburg, PA, pp 181-188.
- James, W. (1890). *The principles of psychology.* New York: Holt (Reprint 1983: Harvard University Press, Cambridge, MA)
- Jonides, J. (1983). Further toward a model of the mind's eye's movement. *Bulletin of the Psychonomic Society* 21, 247-250.
- Kandel, E. R., Schwartz, J. H. & Jessel, T. M. (2000). *Principles of neural science.* USA: McGraw-Hill.
- Kaplan, A. Ya., Brodsky, B. E., Darkhovsky, B. S., Shishkin, S. L., Fingelkurts, Al. A. & Fingelkurts, An. A., (1995). *Change-point mapping: a new technique for EEG brain imaging.* In Proc. First International Conference on Functional Mapping of the Human Brain, *Human Brain Mapping*, 1, 97.
- Kaplan, A. Ya. (1998). Nonstationary EEG: methodological and experimental analysis. *Uspehi Physiologicheskikh Nayk (Success in Physiological Sciences)*, 29, 35-55 (in Russian).
- Kaplan, A. Ya. (1999). The problem of segmental description of human electroencephalogram. *Human Physiology*, 25, 107-114 (Translated from *Physiologiya Cheloveka*).
- La Berge, D. (1983). The spatial extent of attention to letters and words. *Journal of Experimental Psychology: Human Perception and Performance* 9, 371-379.
- La Berge, D. (1995). *Attentional processing. The brain's art of mindfulness.* Cambridge, MA: Harvard University Press.
- Lakoff, G. (1987). *Women, Fire, and Dangerous Things.* Chicago: The University of Chicago Press.
- Lehmann, W. P. (1992). *Historical linguistics: an introduction.* London – New York: Routledge.
- Marchetti, G. (1993). *The mechanics of the mind.* Roma: Espansione.
- Marchetti, G. (1997). *La macchina estetica. Il percorso operativo nella costruzione dell'atteggiamento estetico.* Milano: Franco Angeli.
- Marchetti, G. (2001). *A theory of consciousness.* www.mind-consciousness-language.com
- Marchetti, G. (2003). *Foundations of attentional semantics.* www.mind-consciousness-language.com
- Marchetti, G. (2005a). *The importance of non-attentional operations for Attentional Semantics.* www.mind-consciousness-language.com

- Marchetti, G. (2005b). *Commentary on Giulio Benedetti's "Semantica Operativa", vol I*, 2004. www.mind-consciousness-language.com
- Marchetti, G. (2006). A presentation of attentional semantics. *Cognitive Processing* 7, 163-194.
- Marchetti, G. (2009) Studies on time: a proposal on how to get out of circularity. *Cognitive Processing* 10, 7-40.
- Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review* 63, 81-97.
- Oberauer, K. (2002). Access to information in working memory: exploring the focus of attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 28, 411-421.
- Oberauer, K., Süß, H-M., Schulze, R., Wilhelm, O., Wittmann, W. W. (2000). Working memory capacity - facets of a cognitive ability construct. *Personality and Individual Differences* 29, 1017-1045.
- Parini, P. (1996). *I percorsi dello sguardo*. Ancona: Edizioni Artemisia.
- Pashler, H. E. (1998). *The psychology of attention*. Cambridge, MA: MIT Press.
- Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology* 32, 3-25.
- Posner, M. I. (1994). Attention in cognitive neuroscience: an overview. In: Gazzaniga, M (ed): *The cognitive neurosciences*. Cambridge, MA: MIT Press.
- Posner, M. I. & Cohen, Y. (1984). Components of performance. In: Bouma H., Bowhuis D. (eds) *Attention and performance*. NJ: Erlbaum, Hillsdale.
- Reed, S. K. (1992). *Cognition. Theory and applications*. Belmont, CA: Wadsworth.
- Revonsuo, A. (2006). *Inner Presence. Consciousness as a Biological Phenomenon*. Cambridge, MA: MIT Press.
- Robins, R. H. (1997). *A short history of linguistics*. London: Addison Wesley Longman.
- Rosch, E. (1973). Natural Categories. *Cognitive Psychology*, 4, 328-350.
- Rosch, E. (1978). Principles of categorization. In E. Rosch & B. Lloyd (Eds.), *Cognition and Categorization*. Hillsdale, N.J.: Lawrence Erlbaum Ass.
- Searle, J. R. (1984). *Minds, brains, and science: The 1984 Reith Lectures*. Cambridge, MA: Harvard University Press.
- Searle, J. R. (1994). *The rediscovery of the mind*. Cambridge, MA: The MIT Press.
- Stich, S. (1996). *Deconstructing the mind*. New York-Oxford: Oxford University Press.
- Tanenhaus, M. K., Spivey-Knowlton, M. J., Eberhard, K. M. & Sedivy, J. E. (1995) Integration of visual and linguistic information in spoken language comprehension. *Science* 268, 1632-1634.
- Vaccarino, G. (1988). *Scienza e semantica costruttivista*. Milano: Cooperativa Libreria Universitaria del Politecnico.
- Vaccarino, G. (1997). *Prolegomeni, vol. I*. Roma: Società Stampa Sportiva.
- Vaccarino, G. (2000). *Prolegomeni, vol. II*. Roma: Società Stampa Sportiva.
- Weiskrantz, L. (1988). *Thought without language*. Oxford: Clarendon Press.
- Wierzbicka, A. (1972). *Semantic Primitives*. Frankfurt a. M.: Athenäum.
- Wierzbicka, A. (1989a). Semantic primitives and lexical universals. *Quaderni di Semantica* X, 1, 103-121.
- Wierzbicka, A. (1989b). Semantic primitives: the expanding set. *Quaderni di Semantica* X, 2, 309-332.

- Wierzbicka, A. (1992). The search for universal semantic primitives. In: Pütz M. (ed.), *Thirty Years of Linguistic Evolution* 215-242. Amsterdam/Philadelphia: John Benjamins.
- Yule, G. (1996). *The study of language*. Cambridge: Cambridge University Press.
- Zeman A. (2001). Consciousness. *Brain* 124, 1263-1289.

Chapter 2

A NEW PERSPECTIVE ON HUMAN CONSCIOUSNESS

*Giorgio Marchetti**

University of Urbino, Italy

ABSTRACT

The aim of this paper is to provide an answer to a fundamental question concerning human consciousness: how can we explain the phenomenal quality of our conscious experiences? It is argued that the first-person perspective is the most suitable one to deal with conscious experience. Accordingly, a model is developed on the idea that the person emerges as an entity from the organism's continuous application of its own energy to itself. The model is composed of two main parts: the perceptual system and the schema of self. The perceptual system makes it possible for an organism to be conscious, whereas the schema of self provides the rules that make an organism perceive, move, act, behave, and live in general. The stream of consciousness arises from the uninterrupted interaction of these two systems. The core part of the model is represented by attention. Attention, which is the activity the organism can perform thanks to the nervous energy supplied by the organ of attention, gives the organism the possibility of performing actions capable of directly varying the organism's state of nervous energy. It is this variation that constitutes the phenomenal aspect of consciousness. When acting, the organism can directly experience and feel its actions and the results of its actions, thus making possible the delimitation and emergence of the person.

Keywords: Consciousness, Attention, Nervous Energy, Organ of Attention, Perception, Schema of Self

INTRODUCTION

In this paper I will try to tackle the main problem of human consciousness: how can we explain the phenomenal quality of conscious experience? Many researchers have tried to solve this problem by adopting a third-person perspective. I argue that this perspective is not

* Corresponding author: Email: giorgio.marchetti@nsn.com, info@mind-consciousness-language.com

the most appropriate when analyzing the phenomenal aspect of consciousness, and that a first-person perspective must be adopted instead. To support my argument, I will compare the two perspectives, and present the main drawbacks of the third-person perspective. I will then present my model of consciousness which is developed on a first-person perspective.

The model is composed of two main systems, the perceptual system and the schema of self. The perceptual system is principally based on the organ of attention, sense-organs, somatosensory organs, and a working memory: it enables the organism to be conscious and provides the products that will be processed by the schema of self and contribute to update and modify it. The schema of self, largely based on innate schemas of action and a long-term memory, provides the rules which make our organism perceive, move, act in general and interact with other organisms. From the uninterrupted interaction of the schema of self and the perceptual system the stream of consciousness arises.

The schema of self - once it has learnt and embodied the notion that the organism, by means of conscious perceiving, is able to affect the course of its own actions - provides the organism with a new degree of freedom that gives it the possibility of directly controlling itself. This constitutes the fundamental passage from consciousness to self-consciousness.

Attention is the core part of the perceptual system: it is not only responsible for the selective aspect of consciousness, but also for its phenomenal quality. The organ of attention is the source of the organism's nervous energy; nervous energy is a kind of physical energy and it gives the organism the possibility of operating attentionally; the attentional activity performed by the organism induces a variation in the state of the nervous energy of the organism. It is this variation that constitutes the phenomenal aspect of consciousness. The person emerges as an entity from the organism's continuous application of its own energy to itself: when acting, the organism can directly experience and feel its actions and the results of its actions, thus making possible the delimitation and emergence of the person.

A final section is dedicated to the discussion of the empirical and logical plausibility of the three main assumptions on attention implied by my model of consciousness: attention is necessary for consciousness; attentional activity can be performed because we are provided with the organ of attention that produces nervous energy; attentional activity directly affects the organ of attention, causing a modification of the state of the nervous energy itself, which constitutes the phenomenal aspect of consciousness.

1. THE MAIN PROBLEM OF CONSCIOUSNESS: QUALIA

Many models of consciousness have been proposed in the last decades. Even though most have tackled some important aspects of consciousness, very often offering viable solutions, practically none have successfully addressed what can be considered the main problem of consciousness: its phenomenal and qualitative aspect, or what philosophers call "qualia", that is, the fact that every time we consciously experience something - whether a colour, a sound, pain, pleasure, or something else -, we have a direct experience of it, we "feel" it.

The inadequacy of current theories of consciousness and of available scientific tools to cope with the subjective and qualitative aspect of consciousness has been shown by many authors (see for example Chalmers 1996, Di Francesco 2000, Searle 1992, Zeman 2001). Theoretical positions on consciousness range from those which do not even admit the

legitimacy of the concepts of consciousness and qualia - the so called eliminativist ones (Churchland 1983, Dennett 1991, Rey 1983, Wilkes 1988); to those which, even though they admit the importance of qualia, nevertheless fail to account for them – the reductionist ones (Baars 1988, Crick 1994, Edelman 1989, Edelman and Tononi 2000); to the dualist ones, which, despite taking consciousness seriously, are not able to explain its causal properties and its interactions with the physical world (Block 1995, Chalmers 1996, McGinn 1991).

In my opinion, the fact that no model of consciousness has so far successfully addressed the problem of the phenomenal aspect of consciousness is due to the lack of a proper theoretical perspective that could exhaustively and coherently account for it: which I have called the “first-person perspective” (Marchetti 2001). Most of the current and dominating models of consciousness originate mainly from the long-established “third-person perspective” usually adopted in empirical sciences; only few attempts have been made at elaborating a theory based on a first-person perspective, among which Damasio (1999), Evans’ (1970) proposal of the “self-approach”, Marchetti’s (2001) theory of consciousness, and Varela’s (1996, 1999) and Varela and Shear’s (1999) proposal to reconcile the first- and the third-person approach to consciousness. The importance of the first-person perspective is also acknowledged by Vogeley and Fink (2003), even though mainly in relation to a specific, albeit fundamental, manifestation of consciousness, that is, self-consciousness.

Let us analyze the main differences between the third-person perspective and my proposal of a first-person perspective, and let us consider some examples of theories of consciousness based on a third-person perspective, so as to see the typical drawbacks it entails.

2. TWO DIFFERENT APPROACHES TO CONSCIOUSNESS: THIRD-PERSON PERSPECTIVES AND FIRST-PERSON PERSPECTIVES

2.1. A Comparison between the Two Approaches

The main differences between the third-person perspective and my proposal of a first-person perspective can be so summarized (see also Table 1):

- (a) Third-person perspectives approach a person’s conscious state by describing and analyzing it from the point of view of an external observer. A first-person perspective approaches a person’s conscious state by describing and analyzing it from the point of view of the person who is experiencing that conscious state. Here it is important to highlight that by “describing and analyzing a person’s conscious state from a first-person perspective” I do not mean capturing its phenomenal and qualitative aspect: actually, there is no possibility of transmitting from a person to another person the “what it’s like” qualitative character of a great part of conscious states (unless, most probably, one takes a cable made of neurons from one person’s brain area and connects it directly to the same area of another person, as suggested by Ramachandran and Hirstein 1997), in the sense that we can never know what another person really experiences when seeing “red”, and whether his/her experience of “red” is the same as ours (I say for “a great part” because there is an important exception:

the meanings of words. In fact, when someone says that “he has seen red” we know perfectly well what he means by saying this, because we have the same linguistic and semantic conscious experience as he has, even though we cannot know what he really feels in seeing red, and if he feels the same thing as we feel). Rather, by “describing and analyzing a person’s conscious state from a first-person perspective” I mean understanding how phenomenal experiences are generated by a person who creates them.

- (b) Third-person perspectives analyze the person’s conscious state in relation either to some of its characteristics that can be observed by the external observer (for example: being “unique” albeit “unitary”; reflecting the binding of diverse modalities; being “serially ordered”) or to some other observable event (the person’s brain neural states, the person’s external behavioral reactions, etc.). A first-person perspective describes and analyzes the person’s conscious state in relation to the emergence, formation and development of the person. Here, “emerges” means “being able to exist as a person”, that is, as an entity distinct and differentiated from other entities, beings, and objects. The process of differentiation from other entities implies that the person has the capacity to determine his/her own limits and boundaries, and concurrently the limits and boundaries of other entities: simply put, to determine the relation existing between him-herself and other entities.
- (c) In third-person perspectives, the person’s conscious state, being described and analyzed from the point of view of the external observer, acquires the characteristics (whether they are its being “unique”, “serially ordered”, “largely widespread and broadcast”, or else) assigned to it by the external observer (rather than by the person him-herself). This implies that it assumes and inherits all the functions, meanings, and values that the external observer – more or less unconsciously, unintentionally or unadvertedly – introduces and brings along with him when describing and analyzing it. In a first-person perspective, the characteristics of the person’s conscious state derive from the person’s activity, and, conversely, the person characterizes according to, and emerges from, his/her continuously producing conscious states;
- (d) In third-person perspectives, the role of the person in constituting and characterizing his/her conscious states (and conversely, the role of conscious states in constituting and characterizing the person in turn) are completely overlooked by the external observer. Actually, the characteristics introduced by the external observer (for example, the “uniqueness” of the conscious state, or its being “serially ordered”, etc.) are the result of a person’s (that is, the external observer’s) activity. But, being surreptitiously introduced, they cannot be, and are not, analyzed as such (that is, as the result of the person’s activity). Consequently, they magically appear as inherent, a-priori characteristics, as primary data of a ready-made world, whereas on the contrary they are (a-posteriori) duplications of products of the person’s activity. This gives rise – among other things - to problems of circularity and endless regression: what is a result of the person’s activity is taken to be a basic constituent of that very activity. In a first-person perspective, the role of the person in constituting and characterizing his/her conscious states is fully taken into account. Nothing is surreptitiously introduced, and everything is analyzed and explained as a product of the person’s activity. Conscious states are not constituted by a-priori characteristics.

Table 1. The main differences between third-person and first-person perspectives

	Third-person perspective		First-person perspective
What point of view it implies	The external observer	Some kinds of external observation: • Behaviorism • Information-processing approach	The person who is experiencing the conscious state
How it analyzes the person's conscious state	In relation to characteristics of the conscious state or of some other events observable by an external observer	Some kinds of observable characteristics: • Phenomenal characteristics of the conscious state • Neurophysiological characteristics of the brain	In relation to the emergence, formation and development of the person
How it characterizes the person's conscious state	The person's conscious state acquires the characteristics assigned to it by the external observer	Some examples of characteristics assigned by the external observer: • The uniqueness and unitary appearance of conscious states (Edelman and Tononi 2000); • Conscious states are largely widespread and broadcast (Baars 1988) • Reentry (Edelman 1989) • Coherent oscillations (Singer 1993) • Quantum processes in neuron microtubules (Penrose 1994) • Sensorimotor contingencies (O'Regan & Noë 2001)	The characteristics of the person's conscious state derive from the person's activity
What role it assigns to the person in constituting his/her conscious states	Completely overlooked	Main drawbacks entailed by third-person perspectives: • Circularity, Endless regression • Representationalism	Fully taken into account

2.2. A Critical Review of Some Models of Consciousness Based on the Third-Person Perspective

As we have seen, third-person perspectives describe and analyze the person's conscious state in relation to some of the characteristics of the conscious state itself that can be observed by the external observer. This is the case, for example, of Baars' (1988, 1997a) *Global Workspace* model, and Edelman and Tononi's (2000) *Dynamic Core* hypothesis (see also Edelman 2003).

Baars' *Global Workspace* model is mainly based on the "theater" metaphor of consciousness, that is, the idea that consciousness is the "publicity" organ of the brain. Fundamentally, the "theater" metaphor tries to account for a specific characteristic of conscious experience: that is, its capacity to combine the various and different kinds of information processed by our brain (sensory signals, memories, etc.) into one single kind of "message" that, being widely broadcast, dominates, and prevails over all the others. Consciousness would be a facility for accessing, disseminating, and exchanging information in the brain, and for exercising global coordination and control. Indeed, only a fraction of the brain would seem to directly support conscious experience: Baars' (1988) proposal includes the reticular formation of the brain stem and midbrain, the outer shell of the thalamus and the set of neurons projecting upward from the thalamus to the cerebral cortex. Together they provide the stage for the unconscious audience in the rest of the brain. Baars' model is certainly highly valuable in explaining a number of cognitive processes: the subject's access to information, the influence of unconscious processors, voluntary control, the development of a self-concept, etc. But, as Chalmers (1996) observes, the question of why these processes should give rise to phenomenal experience is simply not addressed. The best that Baars' theory can do is to state that the information processed within the Global Workspace is experienced because it is globally accessible. But the question of why global accessibility should give rise to conscious experience remains unanswered. Not having directly and positively addressed the problem of the phenomenal aspect of consciousness, but rather having addressed derivative characteristics of conscious states (such as being "largely widespread and broadcast"), Baars' model can explain the latter, but not the former.

Edelman and Tononi's (2000; see also Edelman 2003) *Dynamic Core* hypothesis tries to account for the contrast between the diversity and changeability of conscious states and the unitary appearance to the conscious individual of each conscious state, that is, for the fact that any particular conscious scene is experienced at once as "integrated", "all of a piece" and as "differentiated", in the sense of being "unique". The dynamic core hypothesis proposes that the occurrence of any particular conscious state correlates with a "highly informative discrimination" in a multidimensional space of signals: in neural terms, this would mean that the neural mechanisms underlying consciousness consist of a functional cluster in the thalamocortical system, within which reentrant neuronal interactions yield a succession of differentiated yet unitary metastable states. The dynamic core hypothesis also proposes a quantitative way of measuring "neural complexity" (that is, the extent to which the dynamics of a neural system are both integrated and differentiated), high values of which are suggested to accompany consciousness. Edelman and Tononi, despite providing a neural explanation of qualia (in their view, qualia correspond to the higher-order discriminations entailed by the activity of the neural system), admit that a third-person description of qualia cannot presume to replicate the experience that they imply, and that only an individual can experience the

qualitative properties of qualia: which is tantamount to acknowledging the impossibility for a third-person analysis to fully and properly account for any subjective phenomenal state. Moreover, having based their model of consciousness on some of the characteristics of conscious states (the “uniqueness” of each conscious state, combined with its unitary appearance), they are led to explain the phenomenal aspect of consciousness precisely in terms of those characteristics: consequently, they can only state that the specific property of each quale is determined by the distinctions among the entire set of experienced qualia. This is a typical structural description of phenomena, according to which a given phenomenon is defined on the basis of the relations it has with phenomena of the same kind or level. Such a structural description unavoidably engenders a circular explanation of qualia, which it is impossible to get out of, and which cannot provide any positive account of why a certain differentiated yet unitary metastable neural state should turn into a certain phenomenal experience, and why the phenomenal experience should possess precisely the qualitative characteristics it has.

Third-person perspectives describe and analyze the person’s conscious state in relation not only to some of the characteristics of the conscious state itself, but also to some other kind of observable characteristic, such as the neurophysiological characteristics of the brain. This is precisely what Edelman does, by putting forward his model of consciousness based on the idea of “reentry” (1989, 1992; see also Reeke and Edelman 1995). Reentry is a form of ongoing, reciprocal exchange of signals between neuronal repertoires along parallel anatomical connections. Reentry assures that responses are correlated across different neuronal repertoires at any one time and across similar sensory signalling patterns occurring at different times; it provides: a) pathways that allow current sensory signals to evoke memorial responses in appropriate repertoires; b) a means by which these responses can interact with current responses; c) and, through these interactions, the basis for categorization, learning, and consciousness. According to Edelman, both primary consciousness - which includes an awareness of the world, mental images, but lacks a concept of self and is restricted to the present time - and higher-order consciousness - which includes self-awareness, a sense of time, and language - would arise as a result of re-entrant connectivity and signalling between different neuronal groups of different areas of the brain.

Proposals such as those made by Edelman (1989), which correlate consciousness with some neurophysiological property, present at least two drawbacks. Firstly, they induce us to believe that they are based only on a purely neurophysiological description or analysis, and that no other analytical level is involved. Obviously, this is wrong. If we consider Edelman’s proposal, for example, we can see that his idea that consciousness arises as a result of re-entrant connectivity and signalling between different neuronal groups of different areas of the brain is inspired by one of the main features of consciousness, which is the possibility it gives us of continuously accessing, monitoring and controlling our own conscious functioning and products: this shows that a neurophysiological description of consciousness is never pure or sufficient, and that it must always be preceded or accompanied by some kind of consideration deriving from observations that are performed at some other and different level (for example, the one characteristic of folk psychology: on this point, see Pylyshyn, 1984; see also Humphrey 2006).

Secondly, as observed by O’Regan & Noë (2001), the problem with proposals such as Edelman’s is that they do little to elucidate the mystery of consciousness. The presence of some neurophysiological characteristics, such as Edelman’s re-entrant signalling between

cortical maps, Singer's (1993) coherent oscillations, or Penrose's (1994) quantum processes in neuron microtubules, does not in itself explain the phenomenal quality of conscious experiences. Even if one particular mechanism – for example, coherent oscillations – were proven to correlate perfectly with some behavioral measure of consciousness, the solution of the problem of consciousness would simply be postponed: indeed, why and how should coherent oscillations generate consciousness? After all, oscillations are observed in many other branches of science, where they do not generate consciousness.

As we have seen, one of the main problems with third-person approaches is the circularity brought about by the external observer who, while analyzing the mechanism of consciousness from his point of view (rather than from the person's), unavoidably tends to assign to the person's consciousness some ready-made, unanalyzed characteristics (which he himself formed and developed by means of his consciousness), considering them as its basic constituent (rather than its products). One typical example of this problem is the opinion that somewhere in our brain we have an internal representation of the outside world, and that when the representation is activated, we have the kind of vivid and rich conscious experience we all share. This opinion mistakes the result of a process (the vivid, qualitative experience of something) for the basic component of the process itself, thus bringing about circularity, along with all the drawbacks it usually entails. If the phenomenal experience of something derives from the representation we have in our brain of that something, what is the difference between the former and the latter? What are the laws connecting the two? What is the need for us to consciously experience something if we already possess its representation? If the representation has already the qualities it is supposed to account for, where do they come from, given the fact that "experiencing" them cannot account for them? The hypothesis of the existence of internal representation generates more questions and problems than it is supposed to solve. O'Regan & Noë (2001) also show, as far as vision is concerned, the ineffectiveness of the representationalist view: indeed, in order to assure the visual stability and congruity of what is seen, it makes whoever adopts it postulate additional and uneconomical mechanisms that have to compensate for phenomena such as the blind spot, retinal non-homogeneities, the smear that is created by eye saccades. Moreover, as observed by Morris (2004), the representationalist view begs the question of how a brain-state becomes a representation, that is, becomes something different and more than firings of neurons. Appealing to activation levels in a neural network is not enough if we cannot say how they come to be representations: how are we to locate the difference by virtue of which they represent *all and only* those things that they are supposed to represent? We beg the question if we answer by referring to what counts as different for us: indeed, they represent something for us, but are they representations for the brain? What is it that makes the representations represent what they are supposed to represent, and not, instead, the level of glutamate in the brain?

O'Regan & Noë's (2001) proposal to overcome the problems raised by the representationalist view consists in considering conscious perception as something we do, as a mode of exploring the environment in ways mediated by the knowledge of what they call "sensorimotor contingencies". In their view, the qualitative experience we have when we see an object would consist in the knowledge of the relevant sensorimotor contingencies, that is, in knowing that if we make a certain eye movement, the object will change in the particular way typical of what happens when we move our eyes. The differences in the qualitative character of perceptual experiences would correspond to differences in the character of the relevant sensorimotor contingencies.

In my opinion, O'Regan & Noë's (2001) account of conscious experience suffers from the kind of circularity I have described above. If seeing involves testing and mastering the changes that occur through eye, body and attention movements, then the question would now become: How are these "changes" perceived? Who perceives the "changes"? Who is doing the testing? Is there some agent or homunculus perceiving them? Who possesses the knowledge of the sensorimotor contingencies? O'Regan & Noë seem to overlook the fact that their account of conscious experience presupposes, but does not explain, the existence of a person who detects and tests the changes, who knows what will happen when his/her eye will move in a certain direction, and so on: indeed, in order to detect a certain change, there must be someone who detects it, and for whom the change has certain implications, a certain meaning or value. Moreover, as Manzotti and Sandini (2001) observe, O'Regan & Noë's proposal raises the question of why sensorimotor contingencies should explain subjective experience, given the fact that it seems perfectly conceivable that sensorimotor contingencies can exist without any visual qualities or phenomenal experience at all.

3. A NEW MODEL OF CONSCIOUSNESS BASED ON THE FIRST-PERSON PERSPECTIVE

All the examples we have seen in the preceding section show that the third-person perspective is not suitable to tackle the phenomenal aspect of consciousness, because of the incompatibilities between its "objective" methods of investigation and the specific characteristics of the subjective sphere. In order to properly account for it, a different kind of perspective must be adopted: the first-person perspective. The first-person perspective overcomes the drawbacks of the third-person perspective by fully taking into account the role of the person in constituting and characterizing his/her conscious states, and avoiding to surreptitiously introduce external, ready-made characteristics into its analyses and descriptions of the person's conscious state.

In the following paragraphs, I will present my model of human consciousness which was developed using a first-person perspective. Essentially, this model is based on the continuous interaction of two systems:

1. the perceptual system and
2. the schema of self.

The perceptual system, principally based on the organ of attention, sense-organs, somatosensory organs, and a working memory (in which the products of the attentional activity previously performed - such as memories, concepts, meanings of words, thoughts - can be processed), enables the organism to be conscious and provides the products that will be processed by the schema of self and contribute to update and modify it. These products derive from the operations performed by the perceptual system either on the organism or on the environment.

Conversely, the schema of self, largely based on innate schemas of action and a long-term memory, provides the rules which make our organism perceive, move, act in general and interact with other organisms. As a consequence, it provides not only the instructions for the

perceptual system but also the raw material it has to work out: in fact, the actions performed by the organism can be perceived by the perceptual system (even the very action of perceiving) and become available under the form of conscious perceptions for the schema of self. The latter in turn works on the basis of these perceptions to issue a new instruction for the perceptual system and for the organism.

The uninterrupted interaction of the two systems generates the stream of consciousness (James 1890); each interaction between the two systems generates a specific and unique perception. The uniqueness of each “pulse of consciousness” (James 1890) is determined by the particular instructions that the schema of self gives each time to the perceptual system. These instructions in turn vary each time because of the modification of the schema of self by the conscious perceptions. The consistency and coherence of the stream is ensured by the presence of the schema of self, which tends to run the perceptual system and the organism in general according to a hierarchy of principles, goals and rules at the top of which there is one fundamental principle: the principle of survival, which can operationally be translated into the following imperative “operate in order to continue to operate”.

The perceptual system acts as a monitor that continuously checks what is going on inside and outside the organism, and informs the schema of self. Without this kind of information, the schema of self would be kept in the dark about what has happened or is happening within itself and in the environment.

As we will see, what counts more is that the perceptual system provides the schema of self with the necessary information for the definition and development of a self, that is, for its differentiation from the environment.

The fact that the perceptual system monitors the organism implies that the operations and activities of the organism are consciously perceived only after they have been performed. We become aware of what we do only after we have done it (see for example, Libet 2004: but on the limits of Libet’s theory about voluntary acts, see Marchetti 2005). Evidence of this is given by our daily experience: sometimes, we become aware of what we wanted to say only after having said it.

The fact that the schema of self is updated and fed by the perceptual system implies that conscious products play a causal role in human behavior. They not only contribute to modify the schema of self, but supply the organism with the capacity to act autonomously and voluntarily. As Cimatti (2000) points out, the only condition necessary for this to happen is that the organism has a language, and that it uses it not only to communicate its own intentions or the events happening in the environments to other organisms, as animals do, but also to communicate with itself, directing its own attention to itself and to its attentional system (and, consequently, to someone else’s attentional system).

In such a way, the organism is able to control its own attention and actions, and act intentionally. This is what happens when someone says to oneself that it is time to stand up, and then one stands up. This is also what happens when someone tells someone else to control him/herself, and the latter acts accordingly. By repeating these kinds of operations, the schema of self assimilates the notions of autonomy and self-regulation, thus giving the organism the ability to control and plan its own activities.

Now let us see in details how the perceptual system and the schema of self work.

3.1. The Perceptual System

As we have seen in the preceding section, the most suitable perspective to analyze a sentient person is the first-person perspective, because it is centered on the process by means of which a person emerges as such and comes into existence. Such a person can be said to exist and be so when he/she can delimit and control him-herself, his/her operations, movements and intentions, according to the impact his/her actions have on him-herself. This implies that he/she is able to perform a kind of activity that gives him/her the possibility of *directly* knowing him-herself and defining his/her limits. The direct experiences he/she has of him-herself contribute to form and constitute him/her. For instance, the activity he/she performs when trying to reach something unsuccessfully has a direct effect on him-herself, in the sense of modulating his/her own pool of nervous energy by either blocking the nervous energy flow, re-directing its course, or further stimulating it in the same direction (what I mean here by “nervous energy” will become clearer in the following paragraphs: a detailed description is given in sections 4.2 and 4.3). This effect, which constitutes the “feeling” the person has, immediately gives the person the dimension of his/her effort, and the boundaries of his/her body. We could say that the form the person assumes is the outcome of the activity that produces his/her experiences: the person is the result of this activity. It is this activity that gives the person the possibility of existing as such, because only by performing it can the person take a form and differentiate him/herself from other beings and objects. Therefore, describing what a person feels and experiences is describing this activity and its course.

How can this activity make a person have experiences and feelings? I think that an explanation can be found if we conceive:

- (a) The person as the outcome of a special kind of activity (let us call it “attentional activity”) performed by an organism thanks to a special kind of energy (let us call it “nervous energy”) that is supplied by one of its organs (let us call it the “organ of attention”). By means of this energy, the organism can pilot itself by controlling and running some of its organs (the motor organs, the sense-organs, the organ of attention itself, the somatosensory organs, working memory, and the schema of self). This energy is physical and most probably not of a simple kind, but a combination of different kinds: chemical, electrical, etc.). The “organ of attention” is the physical substrate or the nervous structure that is responsible for the production of nervous energy.
- (b) The attentional activity the person performs as what makes his/her state of nervous energy change. This can happen indirectly, through the action of the person on the world, and the subsequent re-action of the world on the person, or directly, through the action of the person on him-herself;
- (c) The conscious experience the person has as the change of the state of nervous energy resulting from performing the attentional activity.

As one can see, this proposal implies three strong assumptions on attention, namely: attention is necessary for consciousness; attentional activity can be performed because we are provided with the organ of attention that produces nervous energy; attentional activity directly affects the organ of attention, causing a modification of the state of nervous energy itself, which constitutes the phenomenal aspect of consciousness. Since the analysis of the empirical

and logical plausibility of these assumptions deserves a specific and detailed discussion, I will dedicate the last section of this work to it, preferring to first present my model of consciousness.

It should be noted that some other authors also highlight the fact that conscious experiences are the product of the person's activity, even though they do not identify this activity with attention. For example, Humphrey (2006, p. 14) claims that sensations are something that the person *creates*: "Something that does not exist before he looks at the screen, and will vanish when he closes his eyes. Some *thing* indeed, a new fact of his own making". Humphrey, however, adopting a typically third-person perspective, and more precisely a behaviorist one, can only conceive sensation as a response to the sensory stimulus (2006, p. 54), and "feeling sensation" as the self-monitoring by the person of his/her own response (2006, p. 90). Consequently, he cannot explain the qualitative aspect of qualia, nor can he avoid falling into the circularity implied by the third-person approach: in fact, how can one explain the "self-monitoring" by the person of his/her own response? Is this self-monitoring still a kind of response? But if it is still a kind of response, there must be someone else who monitors this further response, and so on, in an endless regression.

In my opinion, we can satisfactorily account for the way the person's activity gives origin to consciousness only if we identify this activity with attention, and if we suppose that we can perform attentional activity thanks to the nervous energy supplied by the organ of attention.

In this view, attention has a central and active role. Every time we direct our attention towards an object, we spend our nervous energy on it. At this point, a change in the state of nervous energy may occur, thus making us perceive or feel the object. Clear evidence of this can be found in very common situations. When having certain "negative" sensations, our activity tends to be slowed down or blocked: sensations of sorrow, pain, tiredness, depression, and so on, precisely *consist in* a reduction or block of our energy flow, as if an obstacle was put in the way of our operating (as a consequence of either a full consumption of our nervous energy or a block of the input flow of energy). Conversely, "positive" sensations, such as happiness, wellness, freshness, and so on, *consist in* a beneficial restoration, facilitation or stimulation of our energy flow.

Even sensations that are not as strong give us evidence of the change that our state of nervous energy undergoes because of the working of attention. When we intend to perceive the surface of an object by touching it, we focus our attention on our fingertips: if a limitation is imposed on us, and we cannot further expand our movements and nervous energy in that direction or dimension, then we have a sensation of "hard". On the contrary, a sensation of "soft" arises when we can further expand our nervous energy, as if we had not yet reached a limit.

Therefore, a person's feelings and conscious experiences are the direct result of his/her applying and using his/her attention (whether on the sense-organs, the somatosensory organs, working memory, or attention itself). What he/she does changes his/her state of nervous energy, thus immediately affecting it, and his/her following actions and behavior: that is, the attentional activity performed by the person involves a temporary variation or disequilibrium in the state of his/her nervous energy. This variation or disequilibrium constitutes the phenomenal aspect of consciousness. The amount of nervous energy necessary for the organism to reestablish the equilibrium represents the *quantitative* aspect of the sensation.

The person as such emerges from his/her continuously performing the attentional activity, that is, from his/her continuously using and applying his/her nervous energy. Every time the

person uses his/her nervous energy, the action performed affects his/her source of nervous energy (either blocking the nervous energy flow, or stimulating it, or in some other way), thus resulting in a possible change of the state of nervous energy. These changes of the state of nervous energy constitute the temporary boundaries and limits of the person's activity: as such, they give form to and characterize the person's activity, while also giving form to and characterizing the person him-herself. Therefore, the form the person takes is a result of the way the person applies his/her nervous energy, that is, of the amount of nervous energy used and of the specific dimension (whether physical - visual, tactile, muscular, etc. -, psychological, social, or else) to which the person applies it.

In my model of consciousness, attention no longer plays the purely passive and subsidiary role - with respect to consciousness - that is usually assigned to it by a typically third-person perspective: the information-processing approach. The information-processing approach describes attention as something passive. The metaphors used to describe it, whether a filter (Broadbent 1958), a zoom lens (Eriksen & St. James 1986), a spotlight that moves (Tsal 1983), a gate (Reeves and Sperling 1986), or a selective, amplifying channel (La Berge 1995), all imply that it is seen as a privileged route for events to enter our mind or consciousness, that is, as a kind of mechanism which, letting information come in and be processed by some other device, plays a marginal, passive role. In such a way, the core problem of consciousness - how can we explain the fact that we have subjective, direct experiences of objects? - is devolved to another organ, for example an operating system (Johnson-Laird 1983, 1988), a central processor (Umiltà 1988) or a supervisory system (Shallice 1988). In so doing, however, the information-processing approach does not provide an answer to the problem of consciousness, but simply pushes it back into a deeper hiding place: if we accept the idea of a final device towards which information flows, we should be willing to consider the final device as a conscious agent itself, or a homunculus, thus entering a vicious circle.

The information-processing conception of mind presents the same problems that all third-person perspectives present when studying consciousness. It can certainly explain how information is processed, the changes it undergoes, the time needed to process it, and so on. However, it does not and cannot explain what a person feels as he/she processes information, that is, how his/her conscious states start forming, develop, and change as a consequence of what he/she does. This is because information is made up of ready-made symbols representing the external world, whose meaning derives not so much from the importance they have for the person's formation and development, but from the importance they have for the researcher's investigations. The information-processing approach, in fact, is based on the assumption that the mind processes representations that already have their own meaning, independently from the history of the person, and does not investigate how they acquire a meaning for the person, and how the person builds meaning (Edelman 1989, Freeman 1999 and Searle 1980, 1984, 1992 raise a similar critique to the conception of the mind as a computer and of mental processes as computational).

The information-processing level of analysis examines how some parts of a person's organism - sense organs, attention, memory, central processor, and so on - transform information, but does not examine how a sentient person transforms him-herself as he/she processes information. This is also plainly visible from the way the information-processing approach usually represents the process flow, which can be so schematized:

input > processing unit > output

where: the input is usually a stimulus coming from outside the organism; the processing unit represents some kind of module or unit capable of elaborating and transforming the input; the output is the product of the elaboration performed by the processing unit. This way of representing the process flow leaves some fundamental problems completely unresolved, such as how a certain thing came to be an input for the organism; where the output goes and how it is in turn transformed; why the transformation occurs; how something – for example, a bunch of cells - can turn into an independent entity; etc. Moreover, it says nothing about: the active role that an organism usually plays in its environment; the importance of the exploratory activity of the organism in delimiting and constituting itself and delimiting its own boundaries; how and why something becomes an “input” for the organism; etc.

In my perspective, on the contrary, attention is the fundamental element of conscious processing, a processing which is characterized by two main phases.

Firstly, the continuous application of attention to the other organs (sense organs, the proprioceptive system, the interoceptive system, the musculoskeletal system, and working memory) or to attention itself. This “continuous” working of attention can best be conceived as cyclical, a repetition of successive acts of focalizations each of which has a certain minimal and maximal duration. The hypothesis of the cyclical dynamics of attention, which has been put forward and tested by several researchers (see for example, Large and Jones, 1999, or Ward 2003 who states that attention seems closely associated with alpha and gamma rhythms), can also be inferred from the observation that no one can possibly attend continuously to an object that does not change (James, 1890), or from the tight correlation between the perception of apparent simultaneity and the alpha phase at which stimuli are presented (Varela et al. 1981). The cyclical nature of the working of attention also accounts for the temporal limit of perception known as “phenomenal present” (Vicario 2005), that is, the interval of physical time which, despite being composed of non-contemporaneous parts, is perceived as a unitary and unique act of consciousness, and in which separate events are not differentiated and discriminated, and undergo some process of restructuring and grouping, according to non-temporal principles of organization, such as the Gestalt ones (on the temporal limits of conscious experiences, see also Cabanac 1992, 2002).

Secondly, the modulation of the state of the organ of attention resulting from the application of attention to the other organs or to attention itself. Accordingly, the process flow should be represented as starting not so much from an input coming from outside the organism, as from the actions generated and performed by the organism itself.

As we have seen, in my model of consciousness the *quantitative* aspect of the conscious sensation can be defined as the amount of nervous energy necessary for the organism to reestablish the equilibrium in the state of its nervous energy. The *qualitative* aspect of consciousness, that is, the fact that sensations originating from different perceptual modalities differ qualitatively from each other (a sensation of “hard” is qualitatively different from a sensation of “red”), can be accounted for by the hypothesis that the organ of attention is composed of different parts, each of which is dedicated to processing only a specific kind of information. According to this hypothesis, conscious experiences of different qualities are processed by different, dedicated parts of the organ of attention: when paying attention to a specific perceptual or mental modality, a specific area of the organ of attention is stimulated, and a specific sensation arises. The specificity of each area represents the qualitative aspect of

sensation. Indeed, it would not be possible to explain the qualitative aspect of conscious experiences if we considered the organ of attention as an undifferentiated unit, not divided into sub-specialized units: signals coming, for instance, from different sense-organs would produce qualitatively undifferentiated variations in the state of the nervous energy. The organism would be able to feel only quantitative differences. To explain qualitatively different variations we have then to resort to the concept of an organ of attention subdivided into or composed of different parts.

Such a concept of a segmented organ of attention seems to be well supported by empirical evidence (Pashler 1998). As far as the *perceptual processing stage* is concerned, there is evidence:

- supporting the hypothesis of the existence of modality-specific perceptual attentional systems (that is, separate perceptual attention systems associated with different sensory modalities), instead of a unified polymodal attention system. In fact, people appear capable of selecting visual stimuli in one part of space and auditory stimuli in another part, even if there is a decrement of performance in comparison with selecting visual and auditory stimuli coming from the same side (Driver and Spence 1994); moreover, capacity limits in recognition appear to be more severe when processing multiple stimuli presented through a single modality compared with multiple modalities (Treisman and Davies 1973);
- from divided-attention studies, that, when the total load of stimulus processing does not exceed a certain threshold, subjects are able to process information arriving on more than one channel at a time. In fact, when targets differ from non targets along a simple featural dimension, many elements can be processed in parallel without evident capacity limits (Shiffrin and Gardner 1972); moreover, parallel, unlimited-capacity search is possible when targets are defined by membership in a well-learned symbolic category;

As far as more *central processing stages* (response, selection and more generally thinking) are concerned, there is clear evidence from PRP (Psychological Refractory Period) studies of the existence of dissociations between the central processing stage and the perceptual processing stage. Perceptual analysis, whether overloaded or not, occurs without interference from ongoing central operations (Pashler 1989); there is obligatory queuing of cognitive operations such as response selection and associative retrieval that is independent of sensory modality; certain variables that mitigate perceptual overload do not affect central interference: whereas detecting two attributes of a single object circumvents the perceptual capacity limits (Duncan 1984) that are usually involved whenever two perceptual detections occur at the same time, it does not attenuate the magnitude of central, bottleneck-based interference (PRP effect) (Fagot and Pashler 1992).

The segmentation of the organ of attention into sub-specialized units accounts for the non-parametric, discrete nature of the qualitative dimension of conscious experiences (Cabanac 2002): visual sensations differ from auditory ones, which in turn differ from memories, thoughts, etc. An interesting question related to the qualitative dimension of conscious experiences is whether a hypothetical artificial conscious machine will have the same kinds of conscious experiences that we have or not. In my opinion, such a machine

could theoretically have the same kinds of conscious experiences as we have insofar as it is provided with: (a) an artificial organ of attention, devoted to the supply of nervous energy, segmented in sub-specialized units, and (b) sense organs and somatosensory organs working on the same principles as those governing our sense organs and somatosensory organs. However, if the machine was provided with artificial organs working on different principles, its conscious experiences would differ from ours. I used the term “theoretically”, because one should take into account what Negrotti’s (1997, 1999) work clearly shows: the very use of artificial organs implies unavoidable and unforeseen side effects that tend to differentiate and separate the reproduced object (the artificial conscious machine) from the original exemplar (the human being). Moreover, the use of new materials and processes entails that some performances of the original exemplar cannot be reproduced. On the whole, this would seem to make artificial consciousness really and unavoidably different from human consciousness.

Further to the foregoing description of the perceptual system, I propose the block diagram of Figure 1 as the circuit that is responsible for conscious perception. The figure shows a case of voluntary or endogenous attention. The organism issues instructions to itself to direct its attention toward one or more organs: sense organs, the proprioceptive system, the interoceptive system, the musculoskeletal system, working memory, or the organ of attention itself. The results of the activity performed by these organs (here labeled as “output”) act directly on the relevant area of the organ of attention, making the person have conscious sensations. This is obviously a very schematic representation: for the sake of simplicity, I have represented only some organs and connections; I have also omitted all those circuits – such as the “efferent copy mechanism” (Berthoz 1997, Taylor 2007a) – that, combining sensory information with the person’s expectation and contextual knowledge, help perception resolve ambiguities, and speed up and correct the processing of data (see also Chella 2007, Haikonen 2003, Leonardi 2008).

There can also be, of course, cases of captured or exogenous attention, in which some objects, such as one’s own name (Murray, 1959), capture a person’s attention even though he/she does not expect them or have any intention toward them. In these cases, it seems reasonable to think that a signal coming from the somatosensory system or from some other organ has the power to autonomously capture attention and become conscious, independently of the person’s intention.

As Figure 1 shows, attention can be directed not only toward the other organs, but also toward itself. Among other things, this possibility explains – as I have tried to show elsewhere (Marchetti 2009), following in Mach’s (1890) footsteps, but partially revising his hypothesis – the way we human beings have conscious experience of time. In my view, time-sensation is the perception of the quantity of labor performed by that portion of our attention (let’s call it A_t) that is focused in a continuous and incremental way on the conscious product of the activity performed by means of another portion of one’s attention (let’s call it A_e). The activity performed by A_t represents “temporal activity” (for instance, estimating duration); the activity performed by A_e represents “non-temporal activity” (for instance, perceiving the shape of an object). The amount of nervous energy – supplied by the organ of attention – expended to support the activity of A_t constitutes the basis on which the conscious experience of duration and more in general time-sensation are based (for a similar idea, see Eagleman: “duration is a signature of the amount of energy expended by neurons”, 2008, p. 134).

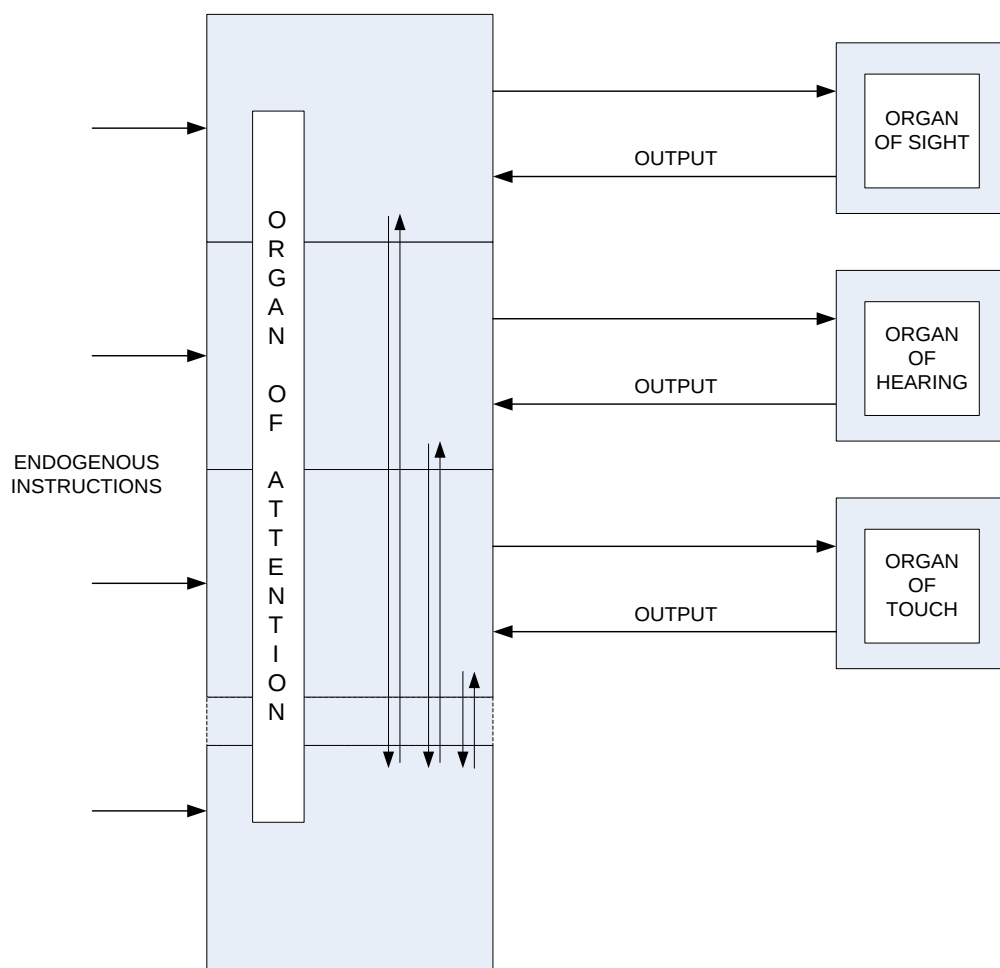


Figure 1. Conscious perception.

3.2. The Schema of Self

The perceptual system provides the necessary raw material for the person to emerge and form. But this is not sufficient. There must also be a device that guides and controls the formation of the person. This device is represented by what I call the schema of self. The schema of self runs the perceptual system and the organism in general according to a hierarchy of principles, goals and rules at the top of which there is one fundamental principle: the principle of survival. Operationally, the principle of survival can be expressed as follows: “operate in order to continue to operate”. This is the vital instinct, the algorithm of life, or more precisely the algorithm of the being (as pointed out by Peter Jakubik, personal communication), which regulates all the other instincts of the organism and its actions. This algorithm makes the organism continue to act and operate, and can only exceptionally be stopped: most probably, it was initially coded in the DNA of the human species as an instruction to maintain the organism’s energetic homeostasis (on how it is possible to maintain the energetic homeostasis, see for example Cabanac and Russek’s model [2000]),

and has subsequently evolved into more sophisticated cultural and social forms (which explains exceptional and counter-intuitive human behaviors such as martyrdom, suicide, heroic sacrifice, etc.)

The schema of self not only incorporates and coordinates all the innate or learned schemata that are necessary to keep the organism alive, but also provides all the rules necessary to guarantee the existence, formation and preservation of the person. To this end, one of the main activities it ensures is defining the person's boundaries, and consequently the differentiation of the person from other organisms, beings, and from his/her environment. The organism defines its boundaries by continuously monitoring its activity and consciously perceiving its own movements, operations, gestures, and so on. The conscious perception of its activity informs it immediately about the dimension, limits and possibilities of its body, and adjusts the rules and components of the schema of self.

To better understand how the interaction between the schema of self and the perceptual system works, we can try to imagine how the interaction could be realized, for example, in a specifically dedicated electronic unit (let's call it *X*), and determine how *X* differs from a standard electronic unit (let's call it *Y*), such as those that can be found in a computer. Obviously, when doing this exercise, we have to consider some important things about our model of consciousness, that is: the main component of the perceptual system is the organ of attention; the organ of attention supplies nervous energy (in this sense, the organ of attention can be assimilated to a kind of power supply unit: but on this issue, see the discussion on the three main assumptions on attention in the last section of this work); nervous energy makes it possible to perform attentional activity; attentional activity directly affects the organ of attention, causing a variation in the state of nervous energy; it is this variation that constitutes the phenomenal aspect of consciousness.

With these things in mind, we can now try to determine the difference between *X* and *Y*. While in *Y* the energy supplied by the power supply unit (whether it is a battery or a generator) depends on, and varies according to, the needs of the circuits it feeds and the operations the circuits are processing (in the sense that the power supply unit supplies as much energy as the circuits require, at least to a certain extent), in *X* it is the operations of the circuit that depend on the variations of the energetic state of the power supply unit, in the sense that the operations of the circuits are modified according to such variations.

The definition of the person's boundaries is made possible by the sensations and feelings the organism has. Until its action can flow undisturbed and is not hindered by anything, the organism feels free, well, pleasure, positively stimulated, etc. Whenever something hinders or blocks its activity, it has to make efforts to overcome the difficulty. These efforts cost it nervous energy, time, pain, frustration, and so on. It is precisely the threshold of effort and pain that marks the limits of the person, and differentiates him/her from its environment. The boundaries of its body are determined by the feelings of pain or frustration it has when acting. The person coincides with his/her action: the person is his/her action.

Any conscious perception of the organism helps to form and mould the person. The person is the outcome of the uninterrupted conscious perceptions of the organism. The process that leads to the emergence of the person can be divided into three main components, and can be represented as in Figure 2.

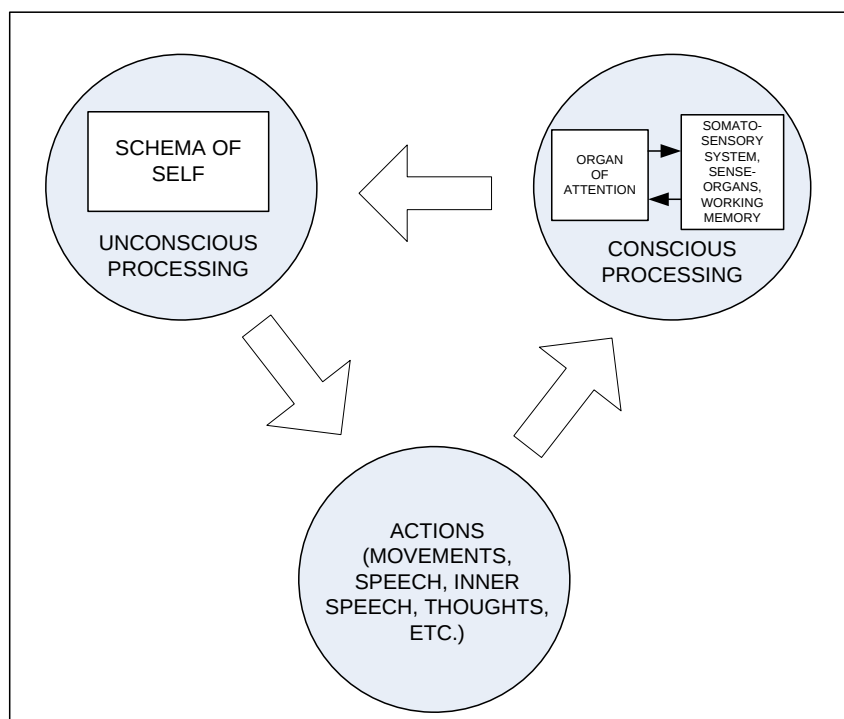


Figure 2. The process that leads to the emergence of the person.

The schema of self, and all the other schemata it incorporates and coordinates, embodies all the competences and abilities - linguistic, social, physical, and so on - the organism innately possesses or has acquired during its life up to that time. It regulates the activities of the organism according to the hierarchy of principles and goals it incorporates, and the rules specific to each kind of competence. Every action the organism performs is caused by the goals of the schema of self - at the top of which there is the principle of survival - and generated and structured by the rules expressed by each kind of competence.

The organism's actions - whether they are represented by a single movement, a coordinated sequence of movements, the production of a sound or a word, inner silent speech, or else - as well as the consequences of the action, can be perceived by the organism. They become the raw material that the perceptual system works out. Since every action unavoidably entails sensations concerning the body and the environment, and the body related to the environment, the organism is able, through them, to understand and define its limits and the limits of the objects of the environment.

Once the organism has consciously perceived its action or the consequence of its action, the information concerning its body, the objects of the environment or the relation between its body and the objects, becomes available for the schema of self, and can be adequately used to update it and adjust the rules of the relevant competence. This process is variously and differently termed and described by some other authors: for instance, Damasio (1999) describes it in terms of the formation in the brain of *first-* and *second-order maps* representing both the organism, the object perceived, and the relationship of object and organism, while Edelman (1989) speaks of the *reentrant mechanisms* allowing categorization and learning.

Incidentally, it should be noted that it has been proposed (for example, Baars 1988) that the language of consciousness is preeminently based on a perceptive, imaginal, spatio-temporal *lingua franca*, and that this is probably due to the fact that the consciousness system is overlaid on an earlier function that is primarily sensory. This implies that whenever we think about, or form a conscious idea of, something, we can do this only through images, sounds, colors, sensations. We always think by means of perceptible objects and things. What cannot be perceived or felt through sense-organs or the somatosensory system cannot be thought about or thought of either. In my view, this is only partially true. It is certainly true that most of our conscious experiences have a perceptive, imaginal aspect, and also that inner speech is made of words that have a sound and a form; however, as I have tried to show (Marchetti 2003), it is equally undeniable that we do have conscious experiences, such as the meanings of words and sentences, beliefs, intentions, that do not have the qualitative and phenomenal properties belonging to images and perceptions originated by our sense-organs or somatosensory system (on this topic, see also Ramachandran & Hirstein 1997, who distinguish between strong, vivid qualia, such as percepts, and not fully laden qualia, such as beliefs and internally generated images).

Once a thing or object is perceived, it becomes available for the schema of self, which processes it. What takes place inside the schema of self is unconscious. When we hear a certain word, or see a certain scene, it is unknown to us how these facts affect our subsequent behavior, thoughts and attitudes, in the sense that we are not aware of what is happening inside us. It simply happens. After having heard a sentence, some thoughts or images appear unexpectedly, but we do not know where they have come from and why only they have appeared, instead of something else. We can suppose that this job is done by some mechanism, such as the collections of specialized unconscious processors described by Baars (1988), and that the job is done following a certain sequence of steps, such as that described by Piaget (1967), but we are conscious neither of the mechanism, nor of its job.

The fact that the schema of self is updated and fed by the perceptual system implies that what the organism consciously perceives plays a causal role in its behavior. *This is one of the most important features of consciousness: it gives the organism the possibility of setting its own aims and objectives, and modifying autonomously its own schema of self.* The schema of self - once it has learnt and embodied the notion that the organism, by means of conscious perceiving, is able to affect the course of its own actions - provides the organism with a new degree of freedom that gives it the possibility of directly controlling itself. Without this further degree of freedom, the updating of the schema of self would take place only in consequence of the actions that the organism performs because of its innate instincts (and the limited set of rules that it could have learnt on the basis of these instincts). Thanks to this new degree of freedom, the schema of self is updated by the actions that the organism voluntarily and autonomously takes. This means that the schema of self, whose main goal is to keep the organism operating, succeeds in equipping the organism with the capacity to self-regulate itself, and consequently find on its own the best ways and means of assuring its survival and of creating new strategies and aims. This constitutes the fundamental passage from consciousness to self-consciousness. The organism's attitude can then change from a purely reactive to a proactive one.

From that moment on, the schema of self runs the organism in such a way that its actions are primarily and directly governed not so much by its innate instincts as by what happens in its consciousness, even though the latter can be occasioned by the former. Every action the

organism performs is a direct consequence of its previous conscious experience. The existence of an uninterrupted and consistent sequence of single units of conscious perception, the Jamesian stream of consciousness (James 1890), is secured precisely by the fact that the previous units play a direct, causal role in the production of the following ones. An interesting neurobiological hypothesis on the brain processes which would instantiate discrete conscious experiences without fundamentally violating the demand for continuity of consciousness is put forward by Fingelkurts and Fingelkurts (2001, 2006). Their key idea is that the temporal synchronization of different brain operations simultaneously executed by different local neuronal assemblies gives rise to a new level of brain abstractness: metastable brain states or “operational modules” (OM). These short-term metastable states change rapidly during transitive fringes or “rapid transitional periods” (RTP). The succession of discrete and relatively stable periods (OMs) separated by abrupt changes (RTP) represents the stream of consciousness.

One of the easiest ways an organism has to control itself and autonomously modify its own schema of self, or at least the easiest way from a human being’s point of view, is by using language. Language can be considered as the most effective and economic way of exploiting the opportunities offered by self-consciousness. Some authors think that self-consciousness could not even be attained without language. According to Cimatti (2000), for instance, what differentiates animals from human beings is precisely the fact that the latter use language not only to communicate their own intentions or the events happening in the environments to other organisms, as the former do, but also to communicate with themselves, directing their own attention to themselves and to their attentional system. By speaking to itself, the organism can “listen” directly to itself, in the sense of listening to its body, mind, intentions, aims, and eventually to its schema of self, without having to wait for the usual physical manifestations - such as coordinated movements of arms, legs, body, and so on - that the schema of self can occasion. Therefore, within certain limits, the organism need not perform actual physical actions in order to perceive itself, its body, the environment, the relations between itself and the environments. Inner speech functions as an artificial behavior that gives the organism the possibility of consciously perceiving itself. In turn, these perceptions continuously modify the schema of self.

Language is not the only way the organism has to exploit the possibilities offered by self-consciousness. Other perceptive modalities can be used as well. Images, sounds, and smells all represent alternative means the organism has to artificially represent itself. However, due to its form and structure, language is no doubt the most common and exploited one. As Vygotskij (1973) pointed out following N. Ach, the original function of words is to direct attention toward something. They serve to isolate certain aspects of objects, and attract attention towards them: as Logan (1995) puts it, semantics specify the computational goals that the attention system must satisfy (on the idea that the meanings of words are based on attentional operations, see the pioneering work of Ceccato, for example, Ceccato 1969, and Ceccato and Zonta 1980. His work has been further developed by Benedetti 2006, 2008, and Marchetti 2006). Through language, adults guide and influence children’s attention, thus getting them to learn how to autonomously master their own attention. But if, as we have seen, attention is the mechanism responsible for consciousness, then learning how to master one’s own attention is tantamount to learning how to master one’s own consciousness.

Languages have many expressions that serve to address the person’s attention not only towards something in general, such as “Look at it”, “Watch me carefully”, “Try to do so and

so”, but also towards the very mechanism of the person’s attention or consciousness, such as “Pay attention to what you are saying”, “Are you aware of what you have done?”, “Try to remember what you have done”. By means of these expressions, the person can control himself and his/her attention, and consequently modify his/her own schema of self. The person can then assume new attitudes and view things under a different light. In turn, the modification of the schema of self entails a new course of actions, thoughts and speeches, which being consciously perceived can further modify the schema of self, and so on. The uninterrupted interplay between the schema of self and what is consciously perceived constitutes the stream of consciousness: the person’s schema of self is continuously modified according to what the he/she consciously perceives, and, conversely, he/she consciously perceives what his/her schema of self occasions.

The block diagram of Figure 3 represents the circuit responsible for the stream of consciousness. The schema of self makes the organism act according to the fundamental principle of survival “operate in order to continue to operate”. The organism can consciously perceive the activity so occasioned, whether it is a movement, a speech, or other, through its various organs (attention, sense-organs and somatosensory system, working memory). The result of the conscious perception updates the schema of self, which in turn issues new instructions to act and perceive.

For sake of simplicity, in Figure 3 I have not represented the internal connections between the various parts of the organ of attention that allow the organism to focus its attention not only toward the other organs, but also toward the organ of attention itself. Nor have I represented all those connections that allow a person to have subliminal perceptions, such as when a stimulus, which has exogenously captured a person’s attention, is unconsciously processed and perceived (McCormick 1997, Merikle et al. 2001): most probably these connections link directly the somatosensory system and the sense-organs to the schema of self, and prevail when there is no sufficient time for the stimuli to be processed to the point of awareness (Libet et al. 1991, McCormick 1997). For example, Libet et al. (1991) showed that an unconscious function may be transformed into a conscious one simply by increasing the duration of the appropriate brain activities to a minimum of about 500 msec. The authors verified this condition by applying stimulus trains of variable duration (from 0 to 750 msec) to a subject’s ascending sensory pathway in the thalamus, and having the subject face a panel containing two buttons, each of which could be lit up briefly alternatively for 1 sec. The subject had to indicate in which of the two lit periods the stimulus was delivered: he had to make that decision even if he were not aware of any sensation produced in the test. The subject then had to report his level of awareness of the stimulus (felt; not certain that it was felt; felt nothing). By a statistical analysis, Libet et al. determined that the difference in stimulus duration between the condition in which the subject responded correctly despite having no awareness of the stimulus, and the condition in which the subject responded correctly having awareness of the stimulus, was due to an increase in stimulus duration of about 400 msec. This duration would represent then the “neuronal code” for the emergence of awareness (see also Libet 2004). Likewise, McCormick (1997), using a cue-target paradigm with informative cues and variable stimulus onset asynchrony (SOA) between the cue and the target (Experiment 3), showed that the effect he found (an exogenous cue presented below a subjective threshold of awareness captures attention automatically and without awareness) is attributable to the time necessary to process the cue to the point of awareness: that is, the

exogenous cuing effect occurs in the unaware condition because observers do not have enough time to complete the processing of the cue before the arrival of the target;

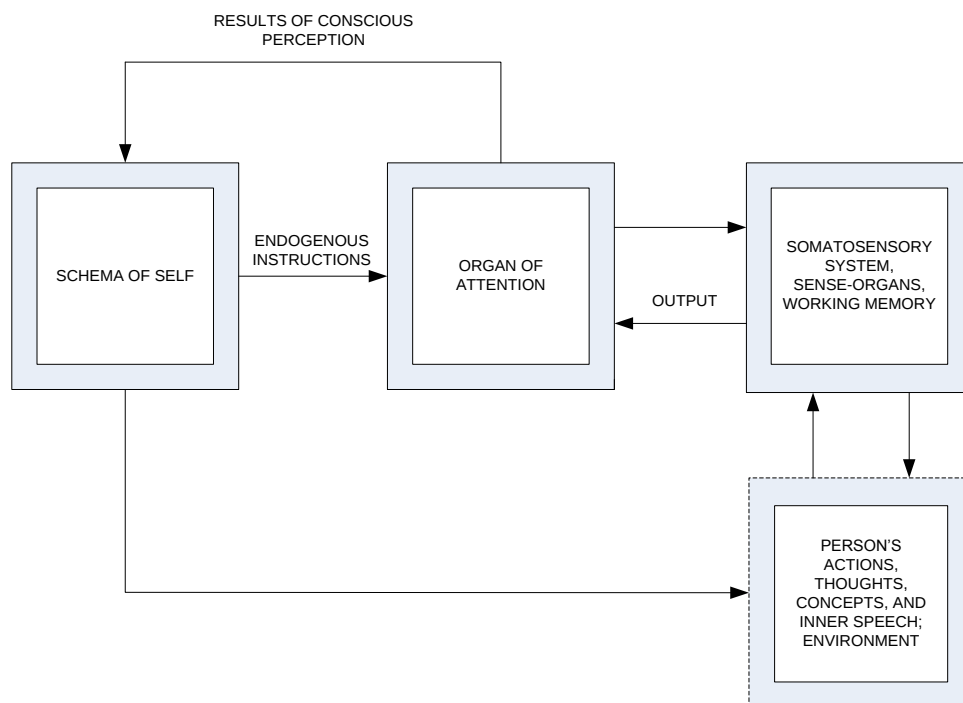


Figure 3. The circuit that generates the stream of consciousness.

Thanks to self-consciousness, the person is able to exert voluntary attention, analyze its own responses and acts, find alternative ways of solving problems, that is, autonomously and voluntarily learn. Automatic, “reflexive” attention can involve learning only as long as innate programs afford it, and animals certainly give evidence of this fact. However, an organism provided only with consciousness cannot learn to learn. Only self-consciousness gives this possibility to the organism. Self-consciousness implies that the organism is conscious of its own operative limits, understands its own boundaries, becomes an autonomous and responsible person, reflects on its own past, decides how and what to learn, and determines its own future.

If consciousness gives the organism the possibility of producing certain results and attaining certain goals that are usually genetically determined, self-consciousness gives it the possibility of autonomously and rationally determining what goals to attain and what results to produce. This is the fundamental difference between consciousness and self-consciousness: while the former lets the organism produce some results, the latter lets it control the operations necessary to produce results.

The difference between consciousness and self-consciousness could be also highlighted in terms of means and ends. As we have seen, studying consciousness means taking a new perspective that considers how a person emerges from an organism’s continuous use and application of its nervous energy. This perspective implies seeing the person as an active

agent personally and directly involved in constructing not only him-herself but also his/her own knowledge. The organism becomes a person because it acts, and, by acting, it differentiates itself from the environment and the other beings, thus getting to know them. An object becomes an object and acquires a meaning for the person only as long as the person can relate the object to him-herself in some way. Therefore, every object can be defined in terms of the person's activity, where "person's activity" means the activity a person has to perform in order to emerge as such. An object exists and has a meaning because a person exists who gives it a meaning, and a person exists because by acting he/she has been able to differentiate him-herself from that object. It is precisely through this activity of differentiation that objects come into existence and acquire a meaning for the person: they become objects and acquire a meaning because through them a person can take shape. Defining an object in this way is viewing it instrumentally, as something that takes part in the construction and definition of the person. In this view, an object is a means a person has of coming into existence. Every object serves the purpose of forming the person, or is somehow associated with this process.

Consciousness, making the person experience directly what he/she is doing and the results of his/her activity, is the privileged way a person has of constructing him-herself, his/her knowledge, objects, and the relation between him-herself and objects. It is through consciousness that a person understands how an object relates to him-herself, learns how to use it, and gets to know it. Consciousness gives the person an immediate understanding of the object and of its meaning. The meaning of the object emerges when the person becomes conscious of it. At that moment, the person understands what relation exists between him-herself and the object, and gives a meaning to the object. At the same time, understanding this implies - for the person - taking a particular shape, namely the shape that the relation makes possible. Therefore, consciousness is the fundamental device by which objects, becoming the means that makes the person take shape, acquire a meaning.

If consciousness gives the person the possibility of assigning a meaning to objects, self-consciousness gives the person the possibility of assigning a meaning to him-herself. Self-consciousness makes it possible for a person to see him-herself as an object, and consequently to become a means to an end. By seeing him-herself as an object, a person can set an end for him-herself, and consider him-herself as an instrument for achieving it. The person then acquires a meaning: the meaning determined by the end he/she has set for him-herself.

4. THE EMPIRICAL AND LOGICAL PLAUSIBILITY OF THE THREE MAIN ASSUMPTIONS IMPLIED BY THIS MODEL OF CONSCIOUSNESS

As we have seen, the central role played by attention in my model of consciousness implies three main assumptions on attention:

- (i) Attention is necessary for consciousness;
- (ii) Attention is a kind of activity that can be performed because we are provided with a form of energy, namely the nervous energy that supplies our organism (this energy is physical and most likely not of a simple kind, but rather a combination of different kinds: chemical, electrical, etc.); this form of energy is produced and supplied by a

physical organ, which I call “the organ of attention”. By the expression “organ of attention”, I mean the physical substrate or the nervous structure that is responsible for the production of nervous energy. We use our nervous energy to pilot our organ of attention and some other organs (the motor organs, the sense-organs, the somatosensory organs, working memory, and the schema of self);

- (iii) Attentional activity directly affects the organ of attention, causing a modification of the state of the nervous energy itself. It is precisely this modification that constitutes the phenomenal aspect of consciousness.

Let's consider these assumptions in detail.

4.1. Attention Is Necessary for Consciousness

The idea presupposed by my model that attention is so strictly linked to, and necessary for, consciousness, is not new (James 1890, O'Regan & Noë 2001, Posner 1994). Indeed, the idea is quite intuitive, if we consider what is thought to be one of the main characteristics of attention: its selective power. When we attend to a certain object or part of an object, we are able to isolate it from the other objects or parts, so that our conscious mind is completely and exclusively possessed and “filled” by it (La Berge, 1995). This shows that there is a direct connection between attention and consciousness: how we pay attention to the world is highly correlated with how the world appears to us. Moreover, well-known psychological phenomena demonstrate that attention modulates perception, directly influencing the way we consciously experience the world. The phenomenon of prior-entry, for example, shows that when a person attends to a stimulus, he or she perceives it as having occurred earlier in time than it would if he or she was not attending to it (Shore et al. 2001). Experiments on duration judgments in which subjects are asked to prospectively judge the duration of the time period they have to perform a certain task, reveal that judged time decreases linearly with the increased processing demands of non-durational information, and that experienced duration increases to the extent that subjects can allocate more attentional resources to the flow of time itself (Brown 1985, Hicks et al. 1976, 1977, Coull et al. 2004): in short, a higher amount of attention allocated to the passage of time itself produces a lengthening of the experienced duration. Carrasco et al.'s experiments (2004) show that attention alters phenomenal appearance: it boosts the apparent stimulus contrast. When observers' transient covert attention (which is the stimulus-driven, exogenous, involuntary capture of attention by an abrupt, salient peripheral cue) is drawn to a stimulus via a peripheral cue, observers report that stimulus as being higher in contrast than it really is, thus indicating a change in appearance with attention.

The idea that attention is necessary for consciousness has received further support from the work of Mack and Rock (1998) and Rensink et al. (1997). For example, in Mack and Rock's (1998) experiments, the subject's attention was engaged in a task (for example, to report the longer arm of a cross briefly presented on the screen and centered at about 2 degrees from fixation). After some trials, an unexpected, unsearched critical stimulus (for example, a black circle) was presented at fixation, and subjects were asked whether they had seen anything that had not been on the screen in the earlier trials. Between 60% and 80% of the observers failed to detect the critical stimulus. A comparison between reports of the

critical stimulus in the inattention trials (where subjects were told to pay attention to the cross, but were not told that a critical stimulus would appear) and those in full attention control (where subjects were told to ignore the cross, and to report only what else they saw on the screen when the cross was present), confirmed that attention is clearly implicated in conscious perception. More in general, Mack and Rock's experiments show that subjects tend to be blind to a critical stimulus that appears either at, or close to, fixation when they are not searching for it, when they are occupied with a task that engages their attention, and when it is located outside the boundaries of the area on which attention is directed. These findings do not imply that there is no implicit, unconscious perception, but only that there is no explicit, conscious perception prior to the engagement of attention. Stimuli to which subjects are inattentionally blind, can be implicitly, unconsciously perceived. In order to bring them into consciousness, they must be attentionally processed.

Mack and Rock's work and Rensink's work, however, do not cover all the possible varieties of forms that attention can assume: indeed, attention can, up to a certain extent, be split between different perceptual and processing modalities (Pashler 1998); it can be either exogenously or endogenously elicited; it can be both widely distributed for relatively long time periods in a certain location (preparatory attention) and narrowly distributed in another location for shorter periods (selective attention) at the same time (La Berge 1995); it varies according to the perceptual load (Lavie 1995); it has one transient component and one sustained component (Nakayama & Mackeben 1989); and so on. Therefore, Mack and Rock's work and Rensink's work lend themselves to criticisms of being only partially valid and applicable. For example, Mole (2008) argues that Mack and Rock's work shows that (focal) attention is necessary for consciousness only in *some* "highly-demanding" circumstances, such as those involving very small or very unexpected changes, learning, unfamiliar situations, etc: it would not show that attention is *in general* necessary for consciousness. Here it is important to note that there are also other cases in which attention is necessary for consciousness, such as when subjects can achieve a good level of performance in identification and detection tasks by means of little focal or preliminary attention (Olivers and Nieuwenhuis 2005). Mole also argues that change-blindness experiments suffer from the defect of not giving the possibility of independently ascertaining whether attention is necessary for consciousness in general: as they are designed, these experiments would only reveal that attention is necessary for consciously detecting changes but not, in general, for being conscious. According to this view, a subject who has not attended to the changing item in the change-blindness pictures could theoretically have some kind of conscious experience, but the experience does not have the "structured content" needed to provide the subject with knowledge of the fact that the thing is changing. In order to avoid such criticisms, Mack and Rock's work and Rensink's work must therefore be further developed. An example of how this can be done is offered by Lavie's research (2006a, 2006b). By manipulating perceptual load in both Mack and Rock's (1998) inattentional blindness paradigm and Rensink et al's (1997) change blindness paradigm, she found that awareness reports depend on the extent to which an attended primary task loads attention: in situations that present a high load on attention, people are unaware of the information to which they do not attend; on the contrary, in situations of low load, due to a "spill-over" of attention, people are aware of other sources of information to which they do not intend to pay attention.

That attention is necessary for consciousness does not imply that attention generates or modulates *only* conscious phenomena: it can also generate and modulate unconscious ones

(Merikle et al. 2001, Naccache et al. 2002, Sumner et al. 2006). For example, Naccache et al. (2002) demonstrate that it is possible to elicit unconscious priming in a number-comparison task, but only if the subject's temporal attention is allocated to the time window during which the prime-target pair is presented: unconscious priming vanishes when temporal attention is focused away from this time window. However, from the fact that attention can also generate unconscious phenomena, it does not follow that there can be focal attention without consciousness: a thesis which is nevertheless held by some authors (Koch and Tsuchiya 2006, Velmans 1991). For example, Velmans (1991) affirms that, "in principle, it might be possible to obtain evidence of focal-attentive processing in the *absence* of awareness of what is being processed" (Velmans, p. 665). He does not claim that an object can be perceived consciously without the intervention of attention. Focal-attentive processing provides the necessary condition for conscious awareness, and there cannot be consciousness without attention: consciousness results from focal-attentive processing as a form of output. However, attention and consciousness are not the same thing, and can be dissociated, because there can be attentional processing without consciousness.

Velmans' aim is to confute the conventional assumption by psychologists that "preconscious" processing is identical to "pre-attentive" processing and "conscious" processing is identical to "focal-attentive" processing. This assumption implies that "preconscious/pre-attentive" processing is involuntary, automatic, fast, and restricted to simple, familiar stimuli, whereas "conscious/focal-attentive" processing is voluntary, subject to intentional control, slow, and flexible. Velmans' confutation is based on evidence that preconscious processing is not inflexible and limited to simple, well-learned stimuli: he supplies many examples of preconscious analysis of novel and complex phrases and sentences, implicit learning, preconscious selection and choice, unconscious control of complex, novel motor adjustments, and unconscious planning. Consequently, it would be misleading to think of the preconscious-unconscious processing of stimuli as non-attended or pre-attentive: preconsciously processed stimuli, being subject to sophisticated, elaborated analysis, *are* receiving attentional resources, although they may not enter consciousness. Moreover, there is evidence (Kahneman and Chajczyk, 1983) that "involuntary, preconscious" analysis of stimuli is not necessarily effortless, and that it draws on, and competes for, limited processing resources, which confirms the involvement of attentional resources in preconscious processing (see also Lavie 1995). Therefore, rather than speaking of non-attended or pre-attentive processing (vs. focal-attentive processing), it would be better to speak of *preliminary attention* (vs. focal attention) (Velmans, 1991. p. 655).

I think that Velmans' work does not demonstrate that focal attention and consciousness are dissociated, as his intention seems to be, but only that "preliminary attention", as he calls it, and consciousness can be dissociated. The cases he takes into consideration give evidence only of the fact that stimuli to which subjects pay limited, preliminary attention are nevertheless preconsciously processed, and therefore that preliminary attention and consciousness can be dissociated. They do not show that there can be focal-attentive processing without consciousness. Whether the evidence he cites refers to dichotic listening tasks and shadowing tasks (Treisman 1964a, 1964b; Lackner and Garret 1973, MacKay 1973), visual masking experiments (Marcel 1980, 1983), Stroop effect, implicit learning (Nissen and Bullemer 1987, Hartman et al. 1987), or control of action, what they all show is only that stimuli can be preconsciously processed on condition that they are given at least a minimal level of attention (as observed by some authors - Neuman 1984, Holender 1986 and

Logan 1995 -, in these cases, as well as in others such as the flanker compatibility effect or negative priming effect - Tipper 1985 -, subjects *do* pay a certain, even if marginal, level of attention to the to-be-ignored, unwanted stimuli, even though they are instructed not to pay attention to them, or are prevented from paying attention to them).

For example, the fact that amnesic patients and normal subjects, exposed to successive exemplars of recurring patterns of which they were unaware, can implicitly learn those patterns without spontaneously noting any repeated sequence (Nissen and Bullemer, 1987, Hartman et al., 1987), does not imply that they have used their focal attention to learn those patterns: in fact, they have been instructed to pay attention to the single items composing each pattern, and not to the recurring pattern. Therefore, it is inappropriate to affirm that there is focal-attentive processing of a pattern in the absence of awareness of that pattern, because what subjects attentively process is not so much the pattern as the single items of the pattern. Most probably instead, they have been able to learn the patterns because they have spent a marginal amount of their attentional resources on it: so marginal an amount that they could not consciously realize what they were doing, even though it was sufficient to make them learn the patterns.

Therefore, Velmans' work is certainly convincing as long as it shows that there can be a limited level of attention (preliminary attention) without consciousness, but it does not prove that there can be focal attention without consciousness.

Most probably, what leads Velmans to claim that consciousness can be dissociated from attention in general, thus overlooking the fact that only preliminary attention, but not focal attention, can be dissociated from consciousness, is the absence of a first-person perspective. As he admits, he adopts a purely information processing perspective, identifying attention with the capacity to process information and analyze stimuli. This perspective certainly gives him the possibility of considering those aspects of mental processing that are usually associated with attention - such as reaction time, accurateness in answering, etc. - but it does not let him see the importance of attention for the emergence and construction of the person. This is because information processing models systematize what can be observed only from a third-person, external observer's perspective, whereas, as we have seen, the phenomenal aspect of attention and consciousness can be analyzed only by taking a first-person perspective. Therefore, it may be that, by assuming the information processing perspective, he has been able to see only one aspect of attention, and this has led him to think that it should be the only one.

An author who, assuming a first-person perspective, does not overlook the fact that only preliminary or low-level (but not focal) attention can be dissociated from consciousness is Damasio (1999). In his definition, consciousness is the "umbrella term for the mental phenomena that permit the strange confection of you as observer or knower of the things observed, of you as owner of thoughts formed in your perspective, of you as potential agent on the scene" (Damasio, 1999, p. 127). Throughout his work, consciousness is seen as the main reason for the feeling we have of ourselves as the subject of our own actions, that is, for the fact that we sense that what we are doing is done by us, and not by someone else. He rightly underlines that the lack of consciousness causes the disappearance of the sense of self: in fact, as we have seen, it is conscious activity that determines the emergence of the person.

According to him, some diseases, such as akinetic mutism, epileptic automatism and advanced stages of Alzheimer's diseases, demonstrate that there can be fleeting, low-level attention without consciousness. Evidence of the dissociation between low-level attention and

consciousness is given by patients who, while exhibiting some elementary signs of attention such as the ability to form sensory images of objects and execute accurate movements relative to those images, do not develop any sense of self, of an individual organism wishing, considering, wanting, of a person with a past and a future. Moreover, they do not show any sign of emotion either. Finally, Damasio points out that only a kind of attention that is high-level, extended in time and focused on appropriate objects is indicative of consciousness (Damasio, 1999, p. 91).

Despite not specifying exactly what the difference is between low-level and high-level attention, these findings seem to support nonetheless, contrary to Velmans' opinion, the hypothesis that focal or high-level attention cannot be dissociated from consciousness. Only low-level attention or, as Velmans calls it, preliminary attention, can be dissociated from consciousness.

The idea that attention is necessary for consciousness is not universally accepted (Baars 1997b, Hardcastle 1997, Koch and Tsuchiya 2006, Lamme 2003, Umiltà, 1994). The view that there can be consciousness without attention may originate either from a third-person approach, from a failure to notice the varieties of forms attention can assume, or from both.

For example, Umiltà (1994) interprets the fact that some objects, such as one's own name (Murray, 1959) or other meaningful stimuli (Mack and Rock, 1998), can capture a subject's attention even though the subject does not expect them or have any intention toward them, as evidence that attention does not coincide with consciousness and that they must be considered as independent systems. In these cases, he argues, the object is perceived consciously in a direct manner, without the intervention of attention. His argument contrasts with what Mack and Rock (1998) have found. They show that there can be no conscious perception without attention, and that by decreasing the probability that attention is paid to an object, the probability of perceiving its presence is reduced. This also applies to cases of captured or exogenous attention: when the difficulty of capture is increased by reducing the attentional zone or increasing the inhibition of attention, the probability that one's own name is reliably perceived decreases (even if it continues to be seen significantly more often than other stimuli). Moreover, as McCormick (1997) has showed, exogenous cues presented below a subjective threshold of awareness capture attention without awareness. These facts indicate that, contrary to Umiltà's opinion, attention is always involved in conscious perception. Even objects such as one's own name cannot be perceived without the intervention of attention: they must capture attention to become conscious. There cannot be conscious perception without attention.

In my opinion, Umiltà's mistake derives from considering consciousness from a purely third-person approach, namely the information-processing one. Like many other authors, he considers mental activity as a particular way of processing information. In this view, consciousness is conceived as a central processor (for a similar view, see Johnson-Laird, 1983, 1988), and attention is a privileged route for events to enter the central processor and become conscious, even though not the only one available (Umiltà, 1988). As a consequence, attention is assigned a passive, subsidiary role in relation to consciousness. As we have seen, this way of considering consciousness cannot explain how it is possible for us to have subjective experiences of things. But it also has another major fault: it cannot account for the constructive role that a person plays in building his/her knowledge. This is due to the fact that its main target is to analyze how a person processes information, and not how a person constructs his/her knowledge. Knowledge construction is not so much a matter of processing

information, the time needed to process it, ways of processing it, and so on, as of *why* a person has to process it. An information-processing approach neither disputes, nor addresses the question of the necessity to process information: it simply analyzes the process, taking the presence both of information, and process and person for granted. On the contrary, a knowledge-construction approach analyzes first of all the origin of information, that is, why and how a person assigns a meaning to objects, and objects acquire a meaning for the person. Only by addressing such questions, is it possible to understand the role played by the person in constructing his/her knowledge.

Overlooking the varieties and complexity of forms that attention and consciousness can assume may also lead to the wrong view that there can be consciousness without attention (on this point, see Bartolomeo 2008, De Brigard & Prinz forthcoming, Posner 2008, and Srinivasan 2008). As we have seen, attention can be split between different perceptual and processing modalities (Pashler 1998); it can be either exogenously or endogenously elicited; it varies according to the perceptual load (Lavie 1995); it has one transient component and one sustained component (Nakayama & Mackeben 1989); and so on. Likewise, a general awareness of our environment (ambient awareness) can be distinguished from a more detailed focal awareness of a scene (focal awareness) (Iwasaki 1993); a form of primary consciousness, including an awareness of the world and mental images, but not a concept of self, can be distinguished from a form of higher-order consciousness, including self-awareness, a sense of time, and language (Edelman 1989); forms of spatial awareness can be distinguished from more reflective forms of consciousness based on intellectual acknowledgment (Bartolomeo 2008); consciousness of sensory qualities differs from volition, which in turn differs from the simple conscious state, which neurology associates with the concept of arousal and the diurnal cycle of sleep and wake (Posner 2008).

For example, Koch and Tsuchiya (2006) quote Li et al.'s (2002) work, which shows that subjects can rapidly detect animals or vehicles in briefly presented novel natural scenes while simultaneously performing another attentionally demanding task, and Reddy et al.'s (2004) work, which, comparing how subjects perform on a face-gender discrimination task carried out in the single-task condition with the same task carried out in the dual-task condition with a known attentional demanding task (5-letter T/L discrimination), shows that the face-gender discrimination task can be performed equally well under the two conditions. According to Koch and Tsuchiya, this kind of evidence shows that there can be consciousness without focal, top-down attention. However, as observed by Taylor and Fragopanagos (2007), in these experiments the subjects underwent up to ten hours of prior training on the stimuli, which makes it highly plausible that the subjects learnt to develop an automatic route to respond to the peripheral stimuli to which they were exposed. Moreover, it is also possible that the subjects were able to use multiple foci of attention to detect the presence of both the peripheral target as well as the main central one (McMains & Somers 2004).

Koch and Tsuchiya (2006) also quote Olivers and Nieuwenhuis' (2005) study on the Attentional Blink as evidence that there can be consciousness in the near absence of focal attention. The Attentional Blink occurs when subjects view rapid serial visual presentations of a series of stimuli presented in the same location, usually at rates of approximately 100 msec per item. Subjects have to detect two target stimuli, T1 and T2; T1 appears first and is followed by T2, which may appear immediately after T1 or at some other point in the sequence after T1, with distractors presented among T1 and T2 (that is, the temporal lag between T1 and T2 can be varied). The blink effect refers to a decrement in detection of T2:

the basic finding is that the decrement is often greatest when T2 occurs not immediately after T1 (position $n+1$), but rather somewhere around positions $n+2$ through $n+5$ (that is, when there is one or more distractors between T1 and T2). The performance improves with higher lag and reaches asymptote around $n+6$ or $n+7$.

Olivers and Nieuwenhuis' (2005) study, which was motivated by the observation that participants in previous experiments reported rather counterintuitively improved T2 performance when being somewhat unfocused on the task, shows that the Attentional Blink is significantly ameliorated when observers are concurrently engaged in distracting mental activity, such as free-associating on a task-irrelevant theme or listening to music. The experiment suggests that under conditions of rapid visual presentation, target detection may benefit from a diffusion of attention.

Koch and Tsuchiya (2006) have interpreted Olivers and Nieuwenhuis' (2005) findings as indicating that top-down attention is not necessary for consciousness. However, as Srinivasan (2008) shows, Olivers and Nieuwenhuis' findings can be interpreted in an alternative and more economical way as implying that some *other form* of attention is necessary for consciousness when stimuli are expected to occur under the specific conditions implied by the Attentional Blink paradigm. Indeed, top-down attention is not a unitary phenomenon; instead it can imply at least two different attentional strategies: focused attention and diffuse attention (Demeyere and Humphreys 2007). As Srinivasan suggests, these two different attentional strategy can be conceived as two ends of a continuum in which the focus varies. Under certain conditions, such as when subjects know that they need to consider a large number of items in order to report the second target stimulus in an experiment on attentional blink, diffused attention may turn out to be a better strategy than focused attention.

Lamme (2003) also proposes that there can be consciousness without attention. In his view, the attentive selection process operates at a later stage than consciousness: attention does not determine whether stimuli reach a conscious state, but determines whether a conscious report about stimuli is possible. In other words, we are conscious of many inputs, but without attention this conscious experience cannot be reported: when we view a visual scene, we experience a richness of content that goes beyond what we can report. His model - which presupposes the existence of a short-lived, vulnerable and not easily reportable form of visual experience, which contrasts with a more stable, reportable form of awareness - parallels: (1) Block's (1996) proposal of the existence of two distinct kinds of awareness: phenomenal and access awareness; and (2) the distinction made in the domain of sensory memory between "iconic memory and "working memory". In support of his view, he quotes Becker et al.'s (2000) and Landman et al.'s (2003) change detection experiments. It is known from Change Blindness' experiments that subjects' ability to detect a change in a visually presented array of items is greatly reduced if a blank interstimulus interval (ISI) is inserted between the original array (stimulus 1) and a subsequent array displaying the same items as stimulus 1 except for one item that has changed (stimulus 2). It is also known that the change detection improves if the to be changed item is cued during the display of stimulus 1. The new and surprising phenomenon found by Becker et al. (2000) and Landman et al. (2003) is that change detection also improves when the location of the change is cued during the blank ISI. This may lead to believe that all of the items of stimulus 1 are conscious, and remain in consciousness even after the stimulus is removed, until it is overwritten by stimulus 2.

In my opinion, Lamme approaches consciousness and attention from a typical information-processing point of view, even though the model he proposes differs from most

of the models that are inspired by such a point of view. Indeed, for him attention is a selection process that determines not so much whether stimuli reach consciousness, as whether stimuli can go from phenomenal awareness to access awareness. He arrives at this model on the basis of the considerations that: (a) there are different levels of processing that stimuli can reach. More specifically, there are sensory inputs that: (1) reach a conscious state via the process of attentive selection; (2) do not reach a conscious state when not attended; (3) do not reach consciousness, not even when attended; (b) these different levels of processing can be more parsimoniously explained by a model that is based on an early distinction between conscious and unconscious stimuli than by a model that is based on an early distinction between attended and unattended stimuli. Indeed, while the early distinction between attended and unattended stimuli would lead to postulating at least three different processes (one for stimuli that are conscious because attended, one for stimuli that are unconscious because unattended and one for stimuli that are purely unconscious), the early distinction between conscious and unconscious stimuli would lead to postulating only two processes (one for stimuli that are conscious and one for stimuli that are unconscious).

There is no doubt that Lamme's information-processing point of view partly explains what hinders him from assigning attention an active role in relation to consciousness. But his model also seems to overlook the fact that both attention and consciousness can assume a variety of forms. For example, when he observes that there are "non-attentional selection mechanisms" that can produce unconscious processing of stimuli, Lamme does not seem to consider the fact that some sort of "preliminary attention" (Velmans 1991) can also exist, and that stimuli that are preliminarily attended, despite being processed, might not be consciously experienced. By overlooking this fact he mistakes unconscious processing for preliminary-attended processing. Moreover, as showed by Bahrami et al. (2008), attention can also act on stimuli that have not reached awareness: stimulus competition for the allocation of attentional capacity occurs regardless of whether or not the observer is conscious of the stimulus representations. Therefore, it certainly seems to be more plausible and economical to propose a model based on the notion that attention is necessary for consciousness than a model based on the idea that attention is not necessary for consciousness: while the latter implies two processes (one for stimuli that are conscious and one for stimuli that are unconscious), the former needs only one process (stimuli are attended: various levels and types of attention are possible).

As regards the finding that change detection improves when the location of the change is cued during the blank ISI (Becker et al. 2000), in my opinion it does not show that there can be consciousness without attention; rather, it only confirms that: (a) there is an early component of attention - namely, the exogenous one (Nakayama & Mackeben 1989) - that can capture a specific item in iconic memory if sufficient time is afforded (change detection and identification tend to worsen at longer ISIs between the offset of stimulus 1 and the onset of the cue); (b) once attention has captured the item, the item is (or can be) transferred to a short-term-memory buffer, where it may be compared with a later-occurring item, thus leading to change detection (change detection and identification tend to improve at longer ISIs between the onset of the cue and the onset of stimulus 2).

Finally, it should be noted that Lamme's idea that when we view a visual scene we experience a richness of content that goes beyond what we can report is questionable at least. Experiments performed with the change-blindness paradigm show that viewers are overconfident about their capacities and suffer from an "illusion of seeing": when viewing a

scene, viewers who claim to perceive the entire visual scene, actually fail to notice important changes of the elements of the scene. As argued by O'Regan & Noë (2001), the "illusion of seeing" might arise because viewers know that they can, at will, orient attention to any location and obtain information from it (for a similar view, see also Dehaene et al. 2006).

One more argument in Koch and Tsuchiya's (2006) view indicating that top-down attention is not necessary for consciousness is the fact that we can be aware of the gist of a scene even when we are not paying attention to it. In my view, the fact that top-down attention is absent or nearly absent does not entail that there is no attention at all: some form of limited attention may be involved, such as for example what Velmans (1991) defines "preliminary attention", which allows us to capture the gist of a scene. This is also De Brigard & Prinz's (forthcoming) view, who observe that there is no reason to think that attention is absent, but rather that it is more plausible to think that attention is only diminished. Indeed, the view that attention is necessary for consciousness predicts very well such findings: when attention is nearly absent, we are aware of far less than when it is fully deployed. This is why the gist is perceived and no more. Alternatively, it is also possible to conceive the phenomenon of gist as evidence of the existence of a specific form of consciousness: what Bartolomeo (2008) calls "primary consciousness". Primary consciousness refers to the basic condition of being aware of something: as such, it must be distinguished from a higher-order, reflective form of consciousness, which can involve linguistic abilities and allows subjects to perceive and describe their own actions and thoughts. Not always what enters primary consciousness also enters the higher-order form of reflective consciousness: overlooking this fact may sometimes lead to the wrong observation that the absence of a verbal report means the absence of consciousness tout court. Bartolomeo (2008, p. 17) illustrates the difference between the two forms of consciousness by quoting an example given by Merleau-Ponty "of someone who enters a room and feels an impression of disorder, only to later discover that this impression came from a crooked picture on the wall. Before discovering that, this person's consciousness was □living things that it could not spell out□. This would by no means imply that the first impression on entering the room was unconscious. Rather, the crooked picture generated a form of consciousness whose source was not immediately amenable to verbal description". Indeed, as showed by Bartolomeo et al. (2007), subjects can use endogenous strategies of attentional orienting - which are traditionally maintained to be voluntary and require conscious awareness - without being able to subsequently describe them.

The fact that attention is necessary for consciousness does not imply that they are the *same* thing. As we have seen, consciousness also needs some other components (sense-organs, somatosensory organs, and a working memory); likewise, the stream of consciousness can only be generated if the schema of self is also added. Moreover, consciousness *results* from the activity performed by attention, that is, from the application of attention to the other organs or to attention itself, and the consequent modulation of the state of the organ of attention. This difference is partly captured by Baars' (1997b) description of attention as something more active than consciousness, and of consciousness as the result of this activity (I say "partly" because, in his theory, Baars only acknowledges the selective function of attention, without recognizing its role in generating the phenomenal, qualitative aspect of consciousness). Indeed, one can wonder whether there can be human consciousness at all, as we know it, without the schema of self (and its fundamental set of rules that runs the perceptual system), the sense-organs, the somatosensory organs, and working memory, and

the connections linking one component to the others and to the organ of attention. This is not the case of course: the organ of attention alone is not sufficient, and the other components are also necessary.

In synthesis, attention represents a key to conscious perception and experience: any model that aims to explain how consciousness works must necessarily include attention as its most important component. Indeed, many models of consciousness take it into consideration, assigning different levels of importance to it (just to mention a few: Baars 1988, Chella 2007, Crick 1994, Edelman 1989). There are also those like Taylor (2002, 2007a, 2007b), who explicitly and extensively uses attention to develop his model of consciousness. Taylor puts forward the CODAM (Corollary Discharge of Attention Movement) neural network control model of consciousness. The CODAM model consists of input processing modules (oriented bar analyzers, etc.), an object representations module (the object map), a goals module, an inverse model controller (creating a feedback attention signal to the object map and input modules, so as to move the focus of attention, as biased by the goals module), a working memory buffer site (to hold attention-amplified activity for report and awareness), a corollary discharge buffer (as a copy of the attention movement signal - that is, the signal that causes the focus of attention to be changed - to give an early prediction of the expected report signal from lower cortices on the buffer working memory), and a monitor module (to create an error signal so as to correct for possible attention errors). The main feature of the model is a speed-up and error-correcting mechanism based on an efference copy or corollary discharge of the attention movement control signal (the signal that causes the focus of attention to change). The corollary discharge provides a precursor signal that not only helps speed up and correct the processing of data, but is also at the basis of the experience of ownership of the about-to-be experienced content of consciousness.

However, despite taking attention into consideration, almost none of these models offers, or intend to offer, an explanation of how attention generates the phenomenal, qualitative aspect of consciousness (to my knowledge, the only partial exception is represented by Haikonen 2003, whose work we will consider later on). This is mainly due to the fact that they are developed using a third-person or purely information-processing approach, which implies all the problems we have seen in the initial paragraphs.

4.2. Attentional Activity Can Be Performed Thanks to Nervous Energy, Which Is Supplied by the Organ of Attention

I derived the idea that attentional activity can be performed because of nervous energy from Ceccato's (1985, p.24; see also Ceccato and Oliva 1988) work, who stated that the human being is provided with a form of energy that can be defined as "nervous" if considered in physiological terms, and as "mental" if considered in attentional ones. Certainly, the concept of "nervous energy" can prove to be quite abstract and problematic for those who, adopting a physical point of view, consider energy as the product of force and distance. However, I think the concept becomes less problematic when we consider the main ideas it wants to convey, namely that: (a) we are provided with "something" that allows us to do perform a certain kind of activity or work, generally known as "mental activity", that is, to think, remember, decide, make plans, feel emotions, perceive, be aware of, perform unconscious processes, etc.; (b) this "something" is limited, in the sense that we can only do a

certain amount of work per unit of time; (c) this “something” dissipates and runs out as we perform mental activity (but can be, at least partly, restored thanks to nourishment, rest and sleep). Considered under this point of view, the concept of “nervous energy” becomes less abstract and can be assimilated to more familiar notions such as “a fuel that is consumed” or a “battery”, even though, as Szalma and Hancock (2002) observe, a major problem with using non-biological metaphors (such as economic or thermodynamic/hydraulic models) to represent biological processes or systems is that the former can fail to capture the complexity and the unique dynamic characteristics of the latter. Indeed, non-biological metaphors may fail to account for some important characteristics of nervous energy, such as the fact that it is a pool that is flexible, in the sense that it fluctuates with arousal, so that in some situations increasing task load may increase arousal, leading to a release of a larger supply of resources. In this sense, as Szalma and Hancock (2002) suggest, a regulatory model based on physiology, such as Cabanac and Russek’s (2000), may prove to be a better metaphor to describe the role of nervous energy in human cognition and performance (even though, as Szalma and Hancock correctly point out, a physiologically-based theory of nervous energy must also be tempered by the problems inherent in reducing psychological processes to physiological activity).

Moreover, it should be noted that the concept of energy and the ideas it conveys are not at all foreign to researchers dealing with brain studies, even though they are not directly used to investigate the mechanisms responsible for the production of qualia. For example, Shulman et al. (2009) observe that high energy consumption is a necessary property of the conscious state. More precisely, empirical evidence from PET and fMRI studies led them to hypothesize that: 1) “the conscious state in the resting-awake human is supported by a high and relatively uniform state of baseline brain energy consumption and (by inference) neuronal activity” (Shulman et al. 2009, p. 66); 2) when the energy is sufficiently reduced, there is loss of consciousness: for example, loss of consciousness during anaesthesia occurs when regional energy levels are uniformly reduced by 40-50% from the resting-awake values; 3) responses to sensory and cognitive inputs are relatively small perturbations of the conscious state, that is, neuronal responses to sensory and cognitive stimuli are much smaller than the neuronal activity maintaining the baseline state.

The concept of energy dissipation and consumption is also taken into consideration for its importance in understanding the function, design and evolution of sense organs and brains (Laughlin 2001, Laughlin & Sejnowski 2003). Indeed, energy consumption can be conceived as a constraint that impinges on all aspects of neural function: as such, it can help understand why nervous systems evolved the way they did. For example, it is known that nervous systems consume metabolic energy at relatively high rates per gram, and that energy supply limits traffic in the brain. As Laughlin & Sejnowski (2003) observe, it is precisely by taking such kinds of metabolic and energy constraints into account that it is possible to explain why evolution favoured the appearance of cortical networks characterized by miniaturized components, in which information is represented with energy-efficient codes and superfluous signals are eliminated.

The ideas implied by the concept of “nervous energy” (nervous energy is a pool that allows us to do a certain kind of work, is limited, runs out, is replenished, is flexible) have been variously highlighted and analyzed in relation to attention by many authors. Various terms – such as “psychic energy”, “limited capacity processor”, “resource”, “effort”, “commodity” and “pool of limited capacity” – have also been used to (either partially or fully)

express the same ideas as those implied by the concept of nervous energy (Peter Jakubik, in a personal communication, also suggests using “operational capability”; however, by adopting “nervous energy”, I intend using a less generic term that identifies one specific kind of energy, and differentiates it from the other kinds of energies: precisely, it identifies the kind of energy that is produced by the organ of attention and used to pilot and run the motor organs, the sense-organs, the somatosensory organs, working memory, and the schema of self).

For example, in his study on the phenomenon of “flow”, Csikszentmihalyi (1992) refers to attention as a psychic energy that allows us to perform mental activity and that is dissipated in doing this activity: “Because attention determines what will or not will not appear in consciousness, and because it is also required to make any other mental events - such as remembering, thinking, feeling, and making decisions - happen there, it is useful to think of it as psychic energy. Attention is like energy in that without it no work can be done, and in doing work it is dissipated. We create ourselves by how we invest this energy” (Csikszentmihalyi 1992, p. 33).

Mach (1890), in his work on time-sensation, speaks of attention in terms of a limited pool that runs out during the day, leading to sleep: “Since, so long as we are conscious, time-sensation is always present, it is probable that it is connected with the organic *consumption* necessarily associated with consciousness, - that we feel the *work of attention* as time. (...) When our attention is completely exhausted, we sleep” (Mach 1890, pp. 111-112).

Kahneman (1973) on the footsteps of David Rapaport, put forward the idea of attention as a limited general purpose resource which can be flexibly allocated from moment to moment according to the person’s needs, goals and motivations. Attention can be focused on one particular activity, or can be divided among a number of activities. When one needs to do two attentionally demanding tasks at once, one can share one’s processing capacities between the tasks according to priority. Moreover, the amount of attentional capacity can vary according to motivation and arousal: if one puts more effort into a task, one can do better. However, since attentional resources are limited, there is a limit to the possibility of sharing attention - when one task demands more resources, there will be less capacity left over for the other tasks - as well as of increasing mental processing capacity by increasing mental effort and arousal.

Although initial research seemed to confirm the existence of the general-purpose resource hypothesized by Kahneman, subsequent experiments (McLeod 1977, 1978, Duncan 1984, Fagot and Pashler, 1992, Pashler, 1989) have shown that there are a variety of resources that are task specific rather than a single, multi-purpose central pool of processing resources. In McLeod’s experiment (1977), for instance, two groups of subjects performed a continuous visual input/manual output task simultaneously with a two-choice tone identification task. While one group responded vocally to the tones, the other group responded with the hand not involved in the continuous tracking task. It was found that the continuous task was performed significantly worse when the two-choice responses were manual, that is, response production was affected by the production of manual responses but not by the production of vocal responses. McLeod concluded that this difference was due to the fact that while the two manual responses were produced by a single limited capacity process, the manual and vocal responses were produced by independent processes. Psychological refractory period (PRP) studies (Pashler, 1998) have also given clear evidence of the existence of independent resources: they show that there is dissociation between the perceptual processing stage and

the central processing stage (roughly speaking, the activity of thinking is, to a certain extent, independent of the activity of perceiving).

Wickens (1984) defined resources as an intervening variable to account for variability in the efficiency with which individuals can divide attention among tasks.

Similarly to the concept of “nervous energy”, the notion of “organ” can also prove to be problematic. In physiology, for example, an “organ” usually denotes something that is anatomically delimited, while in the case of attention it could turn out that many structures are involved at various levels. Therefore, it could be better to use some other term, such as for example “nervous structures”. At present, however, I think the term organ is the preferable one because it requires and conveys the complementary idea of function, which is fundamental at this initial stage of research on the brain structures underpinning consciousness.

Even though the notions of “organ of attention” and of attention as an activity made possible thanks to a form of energy can prove to be problematic for the reasons stated above (and also for some other reasons: see, Navon 1984, Szalma and Hancock 2002), many scientists have nonetheless started investigating the physical substrate of attention and the nervous structures constituting the organ of attention. For example, Mesulam (1990) proposes a network model of attention in which several distinct cortical regions interact. La Berge’s (1995) neural model of visual attention involves the thalamus, the oculomotor regions of the superior colliculus, and the posterior parietal cortex. Posner and his colleagues (Posner 1990, 1995; Posner and Petersen 1990) propose a model of attention consisting of three interconnected networks: a posterior attention network involving the parietal cortex, the pulvinar, and the superior colliculus; an anterior attention network involving the anterior cingulate cortex and supplementary motor areas in the frontal cortex; and a vigilance network involving the locus coeruleus noradrenergic input to the cortex. Each area performs a specific attentional operation: the parietal cortex disengages attention from the locus of the present target; the superior colliculus acts to move the spotlight of attention to the intended target; the pulvinar is involved in the engagement of attention at the intended target; the anterior network, which is involved in the detection of events and the preparation of appropriate responses, exercises executive control over voluntary behavior and thought processes; the vigilance network is crucial for maintaining a state of alertness.

To my knowledge, the individuation of the organ of attention based on the assumptions I have put forward here (that is, as the main organ responsible for the production of conscious experience, which derives from the modulation of the state of nervous energy through the use of nervous energy itself) has not yet been undertaken. It is true that researchers have already started investigating whether attention and consciousness share common neural structures (see for example, Rees and Lavie 2001, Naghavi and Nyberg 2005, Bartolomeo 2008; for a recent review, see Cavanna and Nani, 2008). According to Cavanna and Nani (2008), for example, the frontoparietal network and recurrency (Lamme 2003) could represent the essential neural ingredient of the overlap between consciousness and attention; Bartolomeo (2008) suggests that frontoparietal networks underlie both spatial attention and primary consciousness.

However, this research is still inspired by a limited and partial idea of attention as a purely selective filter, which has the capacity to voluntarily or involuntarily give priority to some parts of the information available at a given moment.

Therefore I cannot provide any empirical evidence for its existence, but only argue for it. Certainly, the empirical individuation of such an organ is not a simple task, above all because of the kinds of basic roles attention plays in mental life. For Haikonen (2003), for example, attention is “a biological neural system’s basic way of favoring the strongest signals, a process that is present already in the simplest central nervous system” (Haikonen 2003, p. 70). For him, therefore, there would be no need for any special “attention box”, since the attention mechanism is distributed within the whole neural system. In my opinion, a successful individuation of such an organ presupposes a clear and comprehensive description of its functions. Only by having previously described such functions and developed a theoretical model of the organ, can scientists identify the physical structures responsible for the production of those functions: using Cavanna and Nani’s (2008) words, “we will not be able to find anything if we do not know exactly what we are looking for”. My proposal is that the organ of attention performs not only those operations that we all know attention allows us to do, such as focusing or zooming on an object, maintaining a state of alertness, selecting items, filtering unwanted information, and so on, but also the fundamental function of generating conscious experience in its various qualitative and quantitative aspects.

4.3. Attentional Activity Affects the Organ of Attention, Causing a Modification of the State of the Nervous Energy Itself, WHICH Constitutes the Phenomenal Aspect of Consciousness

I partly derived the idea that feelings and conscious experiences are the result of a change in the state of nervous energy (induced by the use of nervous energy itself) from Valéry’s (1973) observation that sensation is a variation of the state of energy of a closed system: “Sensation does not consist so much in an introduction of something from the outside, as in an intervention, that is, an inner transformation (of energy) made possible by an external modification, a variation in a state of a closed system (...) sensation is due to some kind of disequilibrium (...) sensation is what occurs between two states of equilibrium” (I have translated this from the Italian version, 1988, pp. 411-412).

This idea seems quite plausible if we assume a first-person perspective. In this perspective, a person emerges from, and thanks to, his/her continuously performing a certain kind of activity (attentional activity). The process of emergence of the person can take place only if the person’s activity allows the person to differentiate him-herself from the other entities, beings, and objects. This implies that the person has the ability to determine his/her own limits and boundaries, and concurrently the limits and boundaries of the other entities. The person’s limits and boundaries are principally represented by the constraints imposed on the person by the specific structure of his/her body (for example, we cannot perform all the movements we want: our body allows us only certain degrees of freedom) and by the relations resulting from the interaction between his/her body and the other entities. Such constraints manifest themselves during the person’s activity and movements, and *are* the basic elements of perception: perception is based precisely on these constraints, and percepts are formed and constituted by these constraints (for a similar view, see Morris 2004. When discussing Carello and Turvey’s [2000] experiments, for example, he states: “What we are

perceiving when we perceive felt length is a constraint, a limit on movement” p. 65). Here it must be stressed that these constraints are the result of the person’s activity, that is, of his/her continuously using and applying his/her attention: they originate from, and are produced by the person’s use of his/her attention, and they *consist precisely of* the interruption, hindrance, slowing down, facilitation, stimulation, acceleration, and so on, of the attentional activity. Every time the person finds an obstacle or cannot extend his/her limbs beyond a certain extent or cannot make a movement, his/her attentional activity, and along with it, all his/her being, is slowed down or even temporarily stopped, so much so that the person must either apply his/her nervous energy in a new way or redirect it to something else, if he/she wants to unblock the situation. It is by means of this use and application of attention that the person can perceive constraints as such (that is, as constraints on his/her own activity). Indeed, the person has no other means of directly “feeling” and experiencing them: the person can only rely on his/her own (attentional) activity. And whoever wants to analyze how a person perceives things also has to rely on the person’s own activity, unless they think that it is better to rely on an internal homunculus, thus falling into endless circularity.

To better understand the mechanism by means of which the attentional activity performed by the organism induces a variation in the state of the nervous energy of the organism, we can resort to the comparison between this mechanism and a standard power supply, such as a battery. Indeed, as we have seen in the previous section, the concept of nervous energy can be assimilated to more familiar notions such as a “battery” or “a fuel that is consumed”. However, there are some important differences in addition to the one we already considered (nervous energy is flexible, in the sense that it fluctuates with arousal): (a) while the working of the battery has only one effect on the battery itself, that is, dissipating its own charge, the working of attention modulates the state of nervous energy, in the sense that it can for example stimulate a larger production of nervous energy, speed it up, hinder it, or block it; (b) while a battery releases energy only when it is needed by a circuit, the working of attention goes on continuously (most probably, as we have seen, in a cyclical way) in waking hours, so much so that we cannot stop thinking, imagining, remembering, perceiving, and more in general having conscious experiences.

A partial but very interesting parallel with my model of how attentional activity affects the state of the nervous energy of the organism is offered by Cabanac and Russek’s (2000) model of regulated biological systems. Cabanac and Russek starts by correctly pointing out that describing regulation in biological systems in the classical terms of control theory presents the disadvantage of not distinguishing signals from energy: control theory is more concerned with signal processing than with energy flow, which is on the contrary the main problem of any living being

A computer, or a T.V. set, are plugged into an infinite energy supply, and energy counts for little in the problem engineers face in building or using them. On the other hand, energy and matter supply is a major problem for animals. It is therefore necessary to revise the concepts of regulation in order to face this specific problem in living beings (Cabanac and Russek 2000, pp. 141-142).

According to Cabanac and Russek, living beings are open systems that accumulate free energy and reduce their entropy at the expense of the energy input: they reach a steady state, such that a constant amount of free energy available for use is maintained, and the input and

output flows of energy are equal and constant. Their capacity of reducing their local entropy and of organizing themselves at the expense of the energy flow through them, may represent the thermodynamic basis of life and evolution. Cabanac and Russek's model of regulation in physiological systems (Figure 4), which is essentially a homeostatic one, is based on a *set point* that indicates the normal level of function. Perturbations of the steady state require the system to compensate for deviations from the set point. The compensation is achieved through a regulation of the input and output flows, which are anatomically distinct (body outflow - urine, heat loss, etc. - is not the same loop as inflow - water intake, heat production, food intake, etc.). The inflow regulation is a negative feedback loop, in which an input subsystem responds to perturbation of the steady state by increasing flow when energy is drained and decreasing it when energy levels rise above the set point. The outflow is a positive feedforward loop in which changes in the state relative to the set point induces changes in the same direction in the output subsystem.

Cabanac (2000) observes that sensations of pleasure and displeasure are strongly dependent on the actual internal state of the system, that is, how much the level of free energy available for the system deviates from the set point: for example, while hypothermic subjects feel cold stimuli as unpleasant and warm stimuli as pleasant, hyperthermic subjects feel the opposite in response to the same stimuli: as soon as subjects return to normothermia, all stimuli lose their strong pleasure or displeasure component and tend to become indifferent.

Thus pleasure can take place only in situations in which an internal perturbation has to be corrected (for example, hyperthermia or hypothermia); once the internal perturbation is corrected through the regulation of the input and output flows, all stimuli become indifferent (unless, of course, the perturbation they introduce in the energy level of the system is such that the pain threshold is reached or crossed, in which case they arouse displeasure).

Cabanac uses the word "alliesthesia" to indicate the fact that the hedonic dimension of sensation is contingent upon the internal state of the stimulated subject: sensory pleasure is a dynamic characteristic eventually generating its own extinction. Therefore, sensory pleasure can be characterized by its physiological usefulness in correcting a physiological trouble or deficit.

If we apply Cabanac and Russek's model to my attentional model, the energy flow becomes the nervous energy which is continuously used by the organism in the form of attention. The application of attention induces perturbations of the energy level of the system, which can generate either pleasant, unpleasant or indifferent sensations.

The hedonic dimension of the sensation - that is, its pleasantness, unpleasantness or indifference - depends substantially on whether the energy level of the system is moving away from, or toward the set point (as we have seen, pleasant sensations occur when perturbations are corrected, bringing the energy level toward the set point, while unpleasant sensations occur when perturbations are introduced, which brings the energy level away from the set point), the distance between the actual energy level and the set point (indifferent sensations occur when the energy level is near the set point; painful sensations occur when the energy level reaches a certain distance from the set point), and most probably the speed at which the energy level moves.

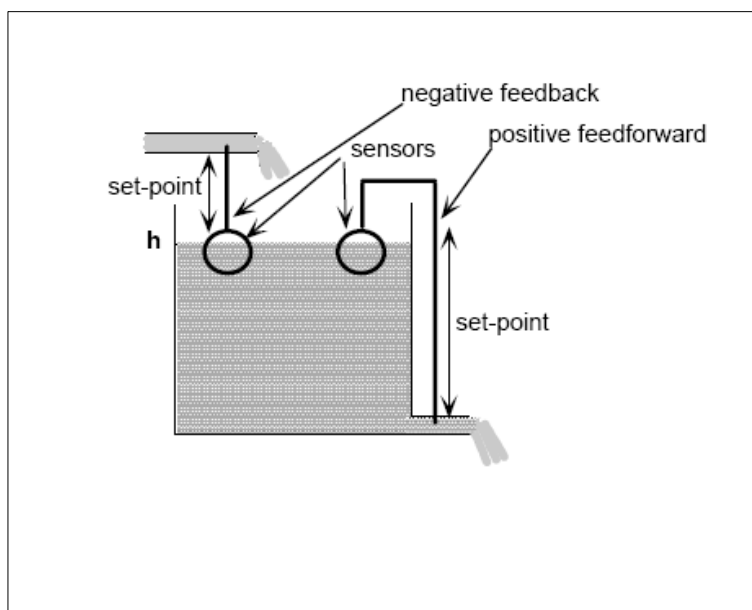


Figure 4. Cabanac and Russek's (2000) model of regulated biological systems.

Let's try to imagine how the internal state modifies when the person, touching a surface, feels a sensation of "soft". The initial application of attention – through the organ of touch - to the surface produces a slight expenditure of nervous energy, which induces a temporary decrease of the energy level of the system. This in turn entails – through the regulatory negative feedback – the opening of the faucet at the input so as to let the energy level rise in order to restore the set point. Subsequently, with the surface of the object not offering any resistance to the fingers, less nervous energy is required at the output. The sudden increased input flow not counterbalanced by an equal output flow makes the energy level return to the set point, with the accompanying sensation of pleasure.

On the contrary, a sensation of "hard" implies, after the initial application of attention, a subsequent increase of output flow, which, not being duly counterbalanced by the input flow, leads to a further decrease of the energy level, with the accompanying sensation of effort and sometimes also displeasure.

As I said, Cabanac and Russek's model offers a partial analogy of my attentional model: for example, it does not address the problem of the segmentation of the organ of attention in specialized sub-units - what Szalma and Hancock (2002) term "structural considerations", nor does it account for the cyclical character of attentional activity – even though, in his other works (Cabanac 1992, 1996, 2002), Cabanac clearly states that every conscious experience is characterized by and can be analyzed along four dimensions, two of which are duration and quality (the other two being intensity and pleasure/displeasure). Cabanac and Russek's model does however represent in an essential and vivid way the main mechanism by means of which attention produces the phenomenal aspect of consciousness.

By offering a model of representation that is common to both human consciousness and the other main physiological functions (such as pulmonary ventilation, blood circulation, etc.), Cabanac and Russek's model also gives biological plausibility, from an evolutionary point of view, to my model of consciousness as a system that evolved from more primitive

ones (according to the old principle *Natura non facit saltum* adopted also by Charles Darwin). The fact that there is continuity between old and new systems, however, does not necessarily imply that there are no differences between them or that they perform comparable functions. Firstly, each system deals with a specific kind of energy. Secondly, while the old ones have the main function of keeping the energy flow and oscillations under control, thus *maintaining* as much as possible a constant amount of free energy available for use, human consciousness has the primary aim of *utilizing* the energy flow and oscillations to the end of controlling the other organs and systems. That is, human consciousness has the privilege of controlling the other organs and systems by means of a unique and common kind of energy: nervous energy.

This latter aspect of my model of consciousness is also well captured by Cabanac's (1996, 2003) idea of the affective dimension of human consciousness as the "common currency" for the trade-offs that take place in the mind to achieve the ranking of priorities and insure that the most urgent motivation has access first to the behavioral final common path: which, in Cabanac's view, is what makes human consciousness useful for the person (for a partly similar idea of the usefulness of the hedonic dimension for the person's choices, see Osvich, 1998).

But there is also another important aspect that, in my view, makes human consciousness useful and above all advantageous for the person: the flexibility it allows. Human consciousness, by controlling the other organs, allows the person to allocate his resources according to the various needs and contexts, thus providing him with a higher degree of freedom and autonomy than the other living beings have. This flexibility is primarily attained by means attention, which the person can voluntarily focus both on his various organs, the other beings and the environment, for variable amounts of time. This flexibility allows the person to also face unexpected and new events, or devise new strategies to overcome unresolved problems. Compared to other living beings that simply react to stimuli according to preprogrammed, inherited patterns of behavior, human beings have the competitive advantage of elaborating new behavioral reactions.

The idea that consciousness arises as a consequence of the modification of the energetic state of the organ of attention induced by the use of attention itself is not at all common amongst scientists dealing with consciousness. However, in my view, it is possible to find a partial suggestion in Haikonen's (2003) idea that some conscious states derive from the modulation of attention. When dealing with the problem of the feelings of pain and pleasure, Haikonen notices that they cannot be explained by means of a sensor detecting the property of an external entity: pain and pleasure are not representations of things and objects of the outside world. They are not properties of a sensed entity. The non-representational nature of pain and pleasure is further exemplified by the fact that we cannot memorize pain and pleasure, and evoke them afterwards. But if pain and pleasure cannot be explained by means of a sensor detecting the property of a sensed entity, how can we account for them? According to Haikonen:

Pain sensors do not sense pain, the sensed entity is cell damage and the caused signal indicates only that pain is to be evoked. Thus the feel of pain is not a representation, instead it is a system reaction. The pain signals themselves do not carry the feel of pain, instead the feel arises from the effects that these signals have on the system and this in turn depends on the way the signals are connected to the system (Haikonen 2003, p. 103).

Therefore, Haikonen considers feeling pain as a “system reaction”. What does this “system reaction” consist of?

Pain “demands attention”; it disrupts any attention that is focused on any ongoing task. Obviously pain signals are transmitted to every modality in the frontal cortex and the message, so to say, is “stop whatever you are doing and try something else so that this signal might stop!”. This is because the pain signal itself does not know who should do what to stop the damage and therefore it has to broadcast its message to everybody and thus disrupt the attended processes within each modality. Pain does not allow the other modalities to relax, instead it tries to stop their present activity and start something else. (...) I consider this disruptive broadcasting as a fundamental property of pain and *I would like to go as far as to propose that the subjective feeling of pain is indeed caused by attention disruption especially in the frontal cortex area* (Haikonen 2003, p. 104).

(it should be noted that, for Haikonen, attention is a biological neural system’s basic way of favoring the strongest signals, a process that is already present in the simplest central nervous system).

In Haikonen’s view, feeling pleasure also is a system reaction: “Pleasure, like pain is not a property of a sensed entity. There is no pleasure to be sensed and represented, instead pleasure is a system reaction that can be evoked by various sensations” (Haikonen 2003, p. 105). More specifically, pleasure entails: a) continuing the pleasure-causing activity to sustain the feeling of pleasure; b) focusing attention on the pleasure-causing activity, and excluding attention on other stimuli; c) memorizing pleasure-causing things and acts, so that they can be identified and repeated in the future. For Haikonen, pleasure, like pain, is connected to attention as well, but in a different way from attention:

While pain uses brute force to disrupt the attention within modalities pleasure tries to sustain its attention focus by having non-related circuits and modules relax. In this way only the pleasure evoking activity will be continued while other activities are suppressed (Haikonen 2003, p. 105).

In addition to pain and pleasure, Haikonen lists some other elementary sensations (“elementary” as opposed to more demanding sensations from a processing point of view, such as the visual and auditory ones) that would elicit a basic system reaction, namely:

- (a) good taste and smell, which elicit positive responses, such as acceptance of, and approaching, the source of the good taste and smell;
- (b) bad taste and smell, which elicit negative responses, such as rejection of, and withdrawal from, the source of the bad taste and smell;
- (c) match, which implies sustained attention;
- (d) mismatch, which implies refocused attention;
- (e) novelty, which implies focused attention.

According to Haikonen, system reactions are direct and rather automatic pre-wired responses to elementary sensations: they do not require a complicated cognitive evaluation of the stimulus or of the situation, thus enhancing the prospects of survival. The various

combinations of system reactions give rise to various emotions: curiosity, astonishment, caution, fear, anger, desire, love, happiness, sadness, envy, horror, etc.

Having explained feelings and sensations (such as pain, pleasure, taste, smell, match, mismatch and novelty, but also beauty and ugliness) in terms of system reactions, Haikonen defines strong qualia as: “temporal behaviour patterns of inner attention caused by system reactions (...) We have strong qualia because we have system reactions that affect attention” (Haikonen 2003, p. 148).

Therefore, Haikonen’s proposal, basing strong qualia on attention, and more precisely on its variations (“I have proposed that ‘pain’, ‘pleasure’, ‘good’ and ‘bad’ get their specific feel via the attention affecting mechanisms”, Haikonen 2003, p. 116) seems to tackle the problem of phenomenal consciousness in a way similar to mine.

However, as far as I understand, there is a fundamental difference between his model of consciousness and my model of consciousness. While in my model, the phenomenal aspect of consciousness is explained with the modification of the energetic state of the organ of attention which is determined and induced by the use of attention itself (in other words: qualia *are* the modifications of the state of nervous energy supplied by the organ of attention), in Haikonen’s model, attentional variation causes subjective feelings, but *is not*, and *does not coincide with*, them. In fact, Haikonen’s model resorts to some additional components (namely, “system state sensors” and their “related perception process”) to explain the phenomenal aspect of consciousness, and how system reactions can be consciously felt:

In order to perceive and internally represent system reactions the system needs *system state sensors* and their related perception process (...) pain, pleasure, taste and smell (good/bad) sensations as well as match/mismatch/novelty states are able to initiate the basic system reactions such as those listed before and also other physiological reactions. These system reactions *are perceived by system sensors and their respective perception process* (Haikonen 2003, p. 113) (italics are mine).

The explanation of how a machine can experience strong qualia is therefore shifted to the perception process (indeed, Haikonen clearly states that: “perception processes are a necessary prerequisite for consciousness”, 2003, p. 149, and that: “Consciousness arises from perception, without percepts there is no consciousness”, 2003, p. 271), pushing it back into another unit. Moreover, recognizing that not all percepts reach consciousness even though they may affect behavior, Haikonen admits that “the perception process alone is not sufficient to explain consciousness” (Haikonen 2003, p. 250). So, what is involved in conscious perception? What is it that makes a percept conscious? According to Haikonen:

the difference between conscious and non-conscious operation would be the level of active cross-connections and binding between modalities; the cross-modality reporting and learning of related associative connections and thus the establishment of episodic memories of the event. In non-conscious operation the cross-connections are minimal and the operation of the different modalities is not unified, it is not about the same topic, there is no binding. In conscious actions the operation of the different modalities would be unified; the inner attention of each modality would be focused on the same topic (Haikonen, 2003, p. 254).

As we can see, Haikonen resorts to the notions that are very well-known in consciousness studies of binding (see for example: Singer 2001) and widespread brain interactions (see for

example Baars 1988). However, this does not yet constitute an explanation of what happens *inside* the perception process module that makes a percept conscious. This certainly represents an explanation of what happens outside the perception process, of how the various perception modules interconnect, and how all the system focuses on the same topic; this can certainly explain some important features of consciousness, such as reportability - that is, the capacity to report, either verbally or in another way, what is consciously experienced - and the facilitation of further associations and actions on the percept. Moreover, there is no doubt that Haikonen's model represents a considerable advance on previous ones for several reasons: compared to Baars's model, for example, it explains in applicable engineering terms how inner speech arises (for a more extensive review of Haikonen's model, see Marchetti 2008). However, it does not explain which mechanisms and operations occur inside the perception module to turn system reactions or any other sensations into strong qualia. As I have tried to show in this work, qualia can be simply explained by resorting to the notion of the modification of the energetic state of the organ of attention induced by the use of attention itself. This notion implies that there no need to move, in an endless regression, the explanation of the phenomenal aspect of consciousness to an additional component, such as the "system state sensors": to account for qualia it is enough to consider the working of attention.

CONCLUSION

In this article I have tried to give an answer to a fundamental question concerning human consciousness: how can we explain the phenomenal quality of our conscious experiences? To answer this question, I resorted to two basic concepts: the perceptual system and the schema of self. The perceptual system makes it possible for an organism to be conscious, whereas the schema of self provides the rules that make an organism perceive, move, act, behave, and live in general. From the uninterrupted interaction of the schema of self and the perceptual system the stream of consciousness arises. Every conscious perception affects the schema of self, modifying and updating it. Every modification of the schema of self implies a new particular instruction to the perceptual system, and in general to the organism. The uniqueness of each single "pulse of consciousness" (James 1890) is determined by the particular instruction that the schema of self gives to the perceptual system each time.

Attention, which can be considered as the core part of the perceptual system, is not only responsible for the selective aspect of consciousness, but also for its phenomenal quality. The organ of attention is the source of the organism's nervous energy; nervous energy gives the organism the possibility of attentionally operating, thus performing actions capable of directly affecting the organism's state of nervous energy. The attentional activity performed by the organism involves a variation in the state of nervous energy. It is this variation that constitutes the phenomenal aspect of consciousness. When acting, the organism can directly experience and feel its actions and the results of its actions, thus making possible the delimitation and emergence of the person.

The schema of self - once it has learnt and embodied the notion that the organism, by means of conscious perceiving, is able to affect the course of its own actions - provides the organism with a new degree of freedom that gives it the possibility of directly controlling

itself. The schema of self, whose main goal is to keep the organism operating, thus succeeds in equipping the organism with the capacity to self-regulate itself, and consequently find on its own the best ways and means of assuring its survival and of creating new strategies and aims. This constitutes the fundamental passage from consciousness to self-consciousness

ACKNOWLEDGMENTS

I would like to express my gratitude to Giulio Benedetti, Michel Cabanac, Pentti Haikonen and Peter Jakubik for their insightful and constructive comments on a previous draft of the paper. I am also thankful to Wendy Piemonte for reviewing the English text. The responsibility for the final version of the work is only mine.

REFERENCES

- Baars, B. J. (1988). *A Cognitive Theory of Consciousness*. Cambridge. Cambridge University Press.
- Baars, B. J. (1997a). *In the Theatre of Consciousness. The Workspace of the Mind*. New York. Oxford University Press.
- Baars, B. J. (1997b). Some essential differences between consciousness and attention, perception, and working memory. *Consciousness and Cognition*, 6, 363-371.
- Baharami, B., Carmel, D., Walsh, V., Rees, G., Lavie, N. (2008). Unconscious orientation processing depends on perceptual load. *Journal of Vision*, 8(3):12, 1-10.
- Bartolomeo, P. (2008). Varieties of attention and of consciousness: evidence from neuropsychology *Psyche*, 14, <http://journalpsyche.org/ojs-2.2/index.php/psyche/issue/current/showToc>
- Bartolomeo, P., Decaix, C., Siéoff, E. (2007). The phenomenology of endogenous orienting. *Consciousness and Cognition*, 16, 144-161.
- Becker, M. W., Pashler, H., Anstis, S. M. (2000). The role of iconic memory in change-detection tasks. *Perception*, 29, 273-286.
- Benedetti, G. (2006). Operational Noology as a new methodology for the study of thought and language: theoretical aspects and possible practical applications. *Cognitive processing*., 7, 217-243.
- Benedetti, G. (2008). A semantics “outside language”: Operational Semantics. *A new semantic theory, based on the nature and structure of thought*. www.mind-consciousness-language.com info@mind-consciousness-language.com
- Berthoz, A. (1997). *Le sens du mouvement*., Paris. Odile Jacob.
- Block, N. (1995). On a Confusion about Consciousness. *Behavioral and Brain Sciences*., 18, 227-287.
- Block, N. (1996). How can we find the neural correlate of consciousness. *Trends in Neurosciences*., 19, 456-459.
- Broadbent, D. A. (1958). *Perception and Communication*. London. Pergamon Press.

- Brown, S. W. (1985). Time perception and attention: the effects of prospective versus retrospective paradigms and task demands on perceived duration. *Perception & Psychophys.*, 38, 115-124.
- Cabanac, M. (1992). What is sensation? In R. Wong (Ed). *Biological Perspectives on Motivated Activities*. Northwood N. J. Ablex.
- Cabanac, M. (1996). On the origin of consciousness, a postulate and its corollary. *Neuroscience and Biobehavioral Reviews*, 20, 33-40.
- Cabanac, M. (2000). What is happiness? In C. Bonnet (Ed.), *Fechner Day.*, (29-34). Strasbourg. The International Society for Psychophysics.
- Cabanac, M. (2002). What is emotion? *Behavioural Processes*, 60, 69-84.
- Cabanac, M. (2003). *La cinquième influence ou la dialectique du plaisir*. Laval. Québec. Les Presses de l'université.
- Cabanac, M. & Russek, M. (2000). Regulated biological system. *Journal of Biological System*, 8, 141-149.
- Carello, C. & Turvey, M. T. (2000). Rotational Invariants and Dynamic Touch. In A. Morton (Ed.), *Touch, Representation and Blindness*. Oxford. Oxford University Press.
- Cavanna, A. E. & Nani, A. (2008). Do consciousness and attention have shared neural correlates? *Psyche*, 14, <http://journalpsyche.org/ojs-2.2/index.php/psyche/issue/current/showToc>
- Ceccato, S. (Ed.). (1969). *Corso di linguistica operativa*. Milano. Longanesi.
- Ceccato, S. & Zonta, B. (1980). *Linguaggio consapevolezza pensiero*. Milano. Feltrinelli.
- Ceccato, S. (1985). *Ingegneria della felicità. Per vincere i grandi e piccoli nemici che s'annidano nella mente*. Milano. Rizzoli.
- Ceccato, S. & Oliva, C. (1988). *Il linguista inverosimile. Una passeggiata fra esperienze ed esperimenti della parola*. Milano. Mursia.
- Chalmers, D. J. (1996). *The Conscious Mind. In Search of a Fundamental Theory*. New York. Oxford University Press.
- Chella, A. (2007). Towards Robot Conscious Perception. In A. Chella & R. Manzotti (Eds.), *Artificial Consciousness* (124-140). Exeter, UK. Imprint Academic.
- Churchland, P. S. (1983). Consciousness: the Transmutation of a Concept. *Pacific Philosophical Quarterly*, 68, 80-93.
- Cimatti, F. (2000). *La scimmia che si parla. Linguaggio autocoscienza e libertà nell'animale umano*. Torino. Boringhieri.
- Coull, J. T., Vidal, F., Nazarian, B. & Macar, F. (2004). Functional anatomy of the attentional modulation of time estimation. *Science*, 303, 1506-1508.
- Crick, F. (1994). *The Astonishing Hypothesis*. New York. Simon and Schuster.
- Damasio, A. (1999). *The Feeling of What Happens. Body and Emotions in the Making of Consciousness*. New York. Harcourt Brace & Co.
- De Brigard, F. and Prinz, J. (Forthcoming). Attention and consciousness. In L. Nadel (Ed.), *Wiley Interdisciplinary Reviews: Cognitive Science*.
- Dehaene, S., Changeux, J. P., Naccache, L., Sackur, J. & Sergent, C. (2006). Conscious, preconscious, and subliminal processing: a testable taxonomy. *Trends in cognitive sciences*, 10 (5), 204-211.
- Demeyere, N. and Humphreys, G. (2007). Distributed and focused attention: Neuropsychological evidence for separate attentional mechanisms when counting and

- estimating. *Journal of Experimental Psychology: Human Perception and Performance*, 33, 1076-1088.
- Dennett, D. (1991). *Consciousness Explained*. Boston. Little Brown and Co.
- Di Francesco, M. (2000). *La coscienza*. Roma Bari. Laterza.
- Driver, J. & Spence, C. J. (1994). Spatial synergies between auditory and visual attention. In C. Umiltà and M. Moscovitch (Eds.), *Attention and Performance 15: Conscious and Nonconscious Information Processing*. Cambridge. MIT Press.
- Duncan, J. (1984). Selective attention and the organization of visual information. *Journal of Experimental Psychology: General*, 113, 501-517.
- Eagleman, D. M. (2008). Human time perception and its illusions. *Current Opinion in Neurobiology*, 18, 131-136.
- Edelman, G. M. (1989). *The Remembered Present: a Biological Theory of Consciousness*. New York. Basic Books.
- Edelman, G. M. (1992). *Bright Air, Brilliant Fire. On the Matter of the Mind*. New York. Basic Books.
- Edelman, G. M. (2003). Naturalizing consciousness: A theoretical framework. *Proceedings of the National Academy of Sciences of the United States of America*, 100 (9), 5520-5524.
- Edelman, G. M. & Tononi, G. (2000). *A Universe of Consciousness: How Matter Becomes Imagination*. London. Penguin.
- Eriksen, C. W. & St. James, J. D. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception and Psychophysics*, 40, 225-240.
- Evans, C. O. (1970). *The Subject of Consciousness*. London. George Allen & Unwin Ltd.
- Fagot, C. & Pashler, H. (1992). Making Two Responses to a Single Object: Implications for the Central Attentional Bottleneck. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 1058-1079.
- Fingelkurts, A. A. & Fingelkurts, A. A. (2001). Operational architectonics of the human brain biopotential field: Towards solving the mind-brain problem. *Brain and Mind*, 2, 261-296.
- Fingelkurts, A. A. & Fingelkurts, A. A. (2006). Timing in cognition and EEG brain dynamics: discreteness versus continuity. *Cognitive Processing*, 7, 135-162.
- Freeman, W. J. (1999). *How Brains make up their Minds*. London. Weidenfeld, Nicolson.
- Haikonen, P. O. (2003). *The Cognitive Approach to Conscious Machine*. Exeter, UK. Imprint Academic.
- Hardcastle, V. G. (1997). Attention versus consciousness: a distinction with a difference. *Cognitive Studies. Bulletin of the Japanese Cognitive Science Society*, 4, 56-66.
- Hartman, M., Knopman, D. S. & Nissen, M. J. (1987). Implicit learning of new verbal associations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15, 1070-1082.
- Hicks, R. E., Miller, G. W. & Kinsbourne, M. (1976). Prospective and retrospective judgments of time as a function of amount of information processed. *American Journal of Psychology*, 90, 431-446.
- Hicks, R. E., Miller, G. W., Gaes, G. & Bierman, K. (1977). Concurrent processing demands and the experience of time-in-passing. *American Journal of Psychology*, 89, 719-730.
- Holender, D. (1986). Semantic activation without consciousness in dichotic listening, parafoveal vision and visual masking. A survey and appraisal. *Behavioral and Brain Sciences*, 9, 1-66.

- Humphrey, N. (2006). *Seeing red: a study in consciousness*. Cambridge, MA. Harvard University Press.
- Iwasaki, S. (1993). Spatial attention and two modes of visual consciousness. *Cognition*, 49, 211-233.
- James, W. (1890). *The Principles of Psychology*. New York. Holt.
- Johnson-Laird, P. N. (1983). *Mental Models: Towards a Cognitive Science of Language, Inference and Consciousness*. Cambridge. Cambridge University Press.
- Johnson-Laird, P. N. (1988). A computational analysis of consciousness. In A. J. Marcel and E. Bisiach (Eds.), *Consciousness in Contemporary Science* (357-368). Oxford. Oxford University Press.
- Kahneman, D. (1973). *Attention and effort*. Englewood Cliffs, NJ. Prentice Hall.
- Kahneman, D. & Chajczyk, D. (1983). Test of the automaticity of reading: Dilution of Stroop effects by colour-irrelevant stimuli. *Journal of Experimental Psychology: Human Perception and Performance*, 9, 497-509.
- Koch, C. & Tsuchiya, N. (2006). Attention and consciousness: two distinct brain processes. *Trends in Cognitive Sciences*, 11 (1), 16-22.
- La Berge, D. (1995). *Attentional Processing. The Brain's Art of Mindfulness*. Cambridge, MA. Harvard University Press.
- Lackner, J. & Garrett, M. F. (1973). Resolving ambiguity: Effect of biasing context in the unattended ear. *Cognition*, 1, 359-372.
- Lamme, V. A. F. (2003). Why visual attention and awareness are different. *Trends in Cognitive Sciences*, 7(1), 12-18.
- Landman, R., Spekreijse, H., Lamme, V. A. F. (2003). Large capacity storage of integrated objects before change blindness. *Vision Research*, 43, 149-164.
- Large, E. W. & Jones, M. R. (1999). The dynamics of attending: how people track time-varying events. *Psychological Review*, 106 (1), 119-159.
- Laughlin, S. B. (2001). Energy as a constraint on the coding and processing of sensory information. *Current Opinion in Neurobiology*, 11, 475-480.
- Laughlin, S. B. & Sejnowski, T. J. (2003). Communication in Neuronal Networks. *Science*, 301, 1870-1874.
- Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 451-468.
- Lavie, N. (2006a). Attention and Consciousness. In M. Velmans and S. Schneider (Eds.), *The Blackwell companion to consciousness* (489-503). Oxford. Blackwell Publishing Ltd.
- Lavie, N. (2006b). The role of perceptual load in visual awareness. *Brain Research*, 1080, 91-100.
- Leonardi, S. (2008). *Cognitive circuits*. www.mind-consciousness-language.com info@mind-consciousness-language.com.
- Li, F. F., VanRullen, R., Koch, C. & Perona, P. (2002). Rapid natural scene categorization in the near absence of attention. *Proceedings of the National Academy of Sciences of the United States of America*, 99, 9596-9601.
- Libet, B. (2004). *Mind Time. The Temporal Factor in Consciousness*. Cambridge, Massachusetts. Harvard University Press.
- Libet, B., Perl, D. K., Morledge, E., Gleason, C. A., Hosobuchi, Y. and Barbaro, N. M. (1991). Control of the transition from sensory detection to sensory awareness in man by the duration of a thalamic stimulus: the cerebral "time-on" factor. *Brain*, 114, 1731-1757.

- Logan, G. D. (1995). Linguistic and conceptual control of visual spatial attention. *Cognitive Psychology*, 28, 103-174.
- Mach, E. (1890). *Contributions to the analysis of the sensations*. La Salle. The Open Court Publishing Company.
- Mack, A. & Rock, I. (1998). *Inattentional Blindness*. Bradford Book. Cambridge, MA. MIT Press.
- MacKay, D. G. (1973). Aspects of the theory of comprehension, memory and attention. *Quarterly Journal of Experimental Psychology*, 25, 22-40.
- Manzotti, R. & Sandini, G. (2001). Does functionalism really deal with the phenomenal side of experience? *Behavioral and Brain Sciences*, 24, 993-994.
- Marcel, A. J. (1980). Conscious and preconscious recognition of polysemous words: Locating the selective effects of prior verbal context. In R. S. Nickerson (Ed.), *Attention and Performance VII*. Hillsdale, NJ. Lawrence Erlbaum Associates.
- Marcel, A. J. (1983). Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology*, 15, 197-237.
- Marchetti, G. (2001). *A theory of consciousness*. www.mind-consciousness-language.com info@mind-consciousness-language.com.
- Marchetti, G. (2003). *"Foundations of Attentional Semantics"*. www.mind-consciousness-language.com info@mind-consciousness-language.com
- Marchetti, G. (2005). Commentary on Benjamin Libet's *Mind Time. The Temporal Factor in Consciousness*. www.mind-consciousness-language.com info@mind-consciousness-language.com
- Marchetti, G. (2006). A presentation of Attentional Semantics. *Cognitive Processing*, 7, 163-194.
- Marchetti, G. (2008). Commentary on Pentti O. Haikonen's *The Cognitive Approach to Conscious machines*. www.mind-consciousness-language.com info@mind-consciousness-language.com
- Marchetti, G. (2009). Studies on time: a proposal on how to get out of circularity. *Cognitive Processing*, 10 (1), 7-40.
- McCormick, P. A. (1997). Orienting attention without awareness. *Journal of Experimental Psychology: Human Perception and Performance*, 23, 168-180.
- McGinn, C. (1991). *The Problem of Consciousness*. Oxford. Basil Blackwell.
- McLeod, P. D. (1977). A dual task response modality effect: Support for multi-processor models of attention. *Quarterly Journal of Experimental Psychology*, 29, 651-667.
- McLeod, P. D. (1978). Does probe RT measure central processing demand? *Quarterly Journal of Experimental Psychology*, 30, 83-89.
- McMains, S. A. & Somers, D. C. (2004). Multiple spotlights of attentional selection in human visual cortex. *Neuron*, 42, 677-686.
- Merikle, P. M., Smilek, D., Eastwood, J. D. (2001). Perception without awareness: perspectives from cognitive psychology. *Cognition*, 79, 115-134.
- Mesulam, M. M. (1990). Large-scale neurocognitive networks and distributed processing for attention, language, and memory. *Annals of Neurology*, 28, 597-613.
- Mole, C. (2008). Attention and Consciousness. *Journal of Consciousness Studies*, 15 (4), 86-104.
- Murray, N. (1959). Attention and Dichotic Listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology*, 11, 56-60.

- Morris, D. (2004). *The Sense of Space*. Albany, NY. SUNY.
- Naccache, L., Blandin, E. & Dehaene, S. (2002). Unconscious masked priming depends on temporal attention. *Psychological Science*, 13, 416-424.
- Naghavi, H. R. & Nyberg, L. (2005). Common fronto-parietal activity in attention, memory, and consciousness: Shared demands on integration? *Consciousness and Cognition*, 14, 390-425.
- Nakayama, K. & Mackeben, M. (1989). Sustained and transient components of focal visual attention. *Vision Research*, 29, 1631-1647.
- Navon, D. (1984). Resources—a theoretical soup stone? *Psychological Review*, 91, 216-234.
- Negrotti, M. (1997). *La terza realtà. Introduzione alla teoria dell'artificiale*. Bari. Dedalo.
- Negrotti, M. (1999). *The Theory of the Artificial. Virtual Replications and the Revenge of Reality*. Exeter, England. Intellect Books.
- Neuman, O. (1984). Automatic processing. A review of recent findings and a plead for an old theory. In W. Prinz, and A. Sanders (Eds.), *Cognition and Motor Processes*. Berlin. Springer.
- Nissen, M. J. & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology*, 19, 1-32.
- Olivers, C. N. & Nieuwenhuis, S. (2005). The beneficial effect of concurrent task-irrelevant mental activity on temporal attention. *Psychological Science*, 16 (4), 265-269.
- O'Regan, J. K. & Noë, A. (2001). A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences*, 24, 939-1031.
- Osvich, A. J. (1998). Outlines of the theory of choice: attitude, desire, attention, will. *Intelligent Control (ISIC). Held jointly with IEEE International Symposium on Computational Intelligence in Robotics and Automation (CIRA), Intelligent Systems and Semiotics (ISAS), Proceedings*, 503-510.
- Pashler, H. E. (1989). Dissociations and dependencies between speed and accuracy: Evidence for a two-component theory of divided attention in simple task. *Cognitive Psychology*, 21, 469-514.
- Pashler, H. E. (1998). *The psychology of attention*. Cambridge, Ma. Massachusetts Institute of technology.
- Penrose, R. (1984). *Shadows of the mind*. Oxford. Oxford University Press.
- Piaget, J. (1967). *La construction du réel chez l'enfant*. Paris-Neochâtel. Delachaux & Niestlé.
- Posner, M. I. (1990). Hierarchical distributed networks in the neuropsychology of selective attention. In A. Caramazza (Ed.), *Cognitive Neuropsychology and Neurolinguistics*. Hillsdale, NJ. Lawrence Erlbaum.
- Posner, M. I. (1995). Attention in cognitive neuroscience: an overview. In M. S. Gazzaniga (Ed.), *Handbook of cognitive neuroscience*. Cambridge, MA. Mit Press..
- Posner, M. I. (1994). Attention: The Mechanisms of Consciousness. *Proceedings of the National Academy of Sciences of the United States of America*, 91, 7398-7403.
- Posner, M. I. (2008). Attentional Networks and the Semantics of Consciousness. *Psyche*, 14, <http://journalpsyche.org/ojs-2.2/index.php/psyche/issue/view/104>
- Posner, M. I. & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, 13, 25-42.
- Pylyshyn, Z. W. (1984). *Computation and Cognition. Toward a Foundation for Cognitive Science*. Cambridge. The MIT Press.

- Ramachandran, V. S. & Hirstein, W. (1997). Three Laws of Qualia. What Neurology Tells Us about the Biological Functions of Consciousness, Qualia and the Self. *Journal of Consciousness Studies*, 4 (5-6), 429-458.
- Reddy, L., Wilken, P. & Kock, C. (2004). Face-gender discrimination is possible in the near-absence of attention. *Journal of Vision*, 4, 106-117.
- Reeke, G. N. & Edelman, G. M. (1995). A Darwinist View of the Prospects for Conscious Artifacts. In G. Trautteur (Ed.), *Consciousness: Distinction and Reflection* (106-130). Napoli. Bibliopolis.
- Rees, G. & Lavie, N. (2001). What can functional imaging reveal about the role of attention in visual awareness? *Neuropsychologia*, 39, 1343-1353.
- Reeves, A. & Sperling, G. (1986). Attention gating in short-term visual memory. *Psychological Review*, 93, 180-206.
- Rensink, R. A., O'Regan, J. K. & Clark, J. J (1997). The Need for Attention to Perceive Changes in Scenes. *Psychological Science*, 8, 368-373.
- Rey, G. (1983). A Reason for Doubting of the Existence of Consciousness. In R. J. Davison et al. (Eds.), *Consciousness and Self-Regulation*, Vol. 3. New York. Plenum.
- Searle, J. R. (1980). Minds, Brains, and Programs. *Behavioral and Brain Sciences*, 3, 417-424.
- Searle, J. R. (1984). *Minds, Brains, and Science: The 1984 Reith Lectures*. Cambridge. Harvard University Press.
- Searle, J. R. (1992). *The Rediscovery of the Mind*. Cambridge. The MIT Press.
- Shallice, T. (1988). Information-processing models of consciousness: possibilities and problems. In A. J. Marcel and E. Bisiach (Eds.): *Consciousness in Contemporary Science* (305-333). Oxford. Oxford University Press.
- Shiffrin, R. M. & Gardner, G. T. (1972). Visual processing capacity and attentional control. *Journal of Experimental Psychology*, 93, 78-82.
- Shore, D.I., Spence, C., and Klein, R. M. (2001), Visual prior entry. *Psychological Science*, 12, 205-212.
- Shulman, R. G., Hyder, F., Rothman, D. L. (2009). Brain Energy Supports the State of Consciousness. *Psyche*, 15, <http://journalpsyche.org/ojs-2.2/index.php/psyche/>
- Singer, W. (1993). Synchronization of cortical activity and its putative role in information processing and learning. *Annual review of Physiology*, 55, 349-374.
- Singer, W. (2001). Consciousness and the binding problem. *Annals of the New York Academy of Sciences*, 929, 123-46.
- Srinivasan, N. (2008). Interdependence of attention and consciousness. In R. Banerjee & B. K. Chakrabarti (Eds.), *Progress in Brain Research*, 168, 65-75.
- Sumner, P., Tsai, Pei-Chun, Yu Kenny & Nachev, Parashkev (2006). Attentional modulation of sensorimotor processes in the absence of perceptual awareness. *Proceedings of the National Academy of Sciences of the United States of America*, 103 (27), 10520-10525.
- Szalma, J. J. & Hancock, P. A. (2002). On Mental Resources and Performance Under Stress. U.S. Army Research Office, MURI-OPUS. *White Paper*.
- Taylor, J. G. (2002). Paying attention to consciousness. *Trends in Cognitive Sciences*, 6 (5), 206-210.
- Taylor, J. G. (2007a). CODAM: A neural network model of consciousness. *Neural Networks*, 20, 983-992.

- Taylor, J. G. (2007b). Through Machine Attention to Machine Consciousness. In A. Chella & R. Manzotti (Eds.), *Artificial Consciousness* (24-47). Exeter, UK. Imprint Academic.
- Taylor, J. G. & Fragopanagos, N. (2007). Resolving some confusions over attention and consciousness. *Neural Networks*, 20, 993-1003.
- Tipper, S. P. (1985). The negative priming effect: Inhibitory effects of ignored primes. *Quarterly Journal of Experimental Psychology*, 37A, 571-590.
- Treisman, A. M. (1964a). Verbal cues, language and meaning in attention. *American Journal of Psychology*, 77, 206-214.
- Treisman, A. M. (1964b). The effect of irrelevant material on the efficiency of selective listening. *American Journal of Psychology*, 7, 533-546.
- Treisman, A. & Davies, A. (1973). Dividing attention to ear and eye. In S. Kornblum (Ed.), *Attention and Performance IV*. New York. Academic Press.
- Tsal, Y. (1983). "Movement of attention across the visual field". *Journal of Experimental Psychology: Human Perception and Performance*, 9, 523-530.
- Umiltà, C. (1988). The control operations of consciousness. In A. J. Marcel and E. Bisiach (Eds.): *Consciousness in Contemporary Science* (334-356). Oxford. Oxford University Press.
- Umiltà, C. (1994). Attenzione e coscienza. In P. Legrenzi (Ed.), *Manuale di psicologia generale*. Bologna. Il Mulino.
- Valéry, P. (1973). *Cahiers*. Ed. by Judith Robinson-Valéry. Paris. Gallimard. (Italian translation, 1988: *Quaderni. Volume terzo*. Adelphi. Milano).
- Varela, F. J. (1996). Neurophenomenology. *Journal of Consciousness Studies*, 3, 330-349.
- Varela, F. J. (1999). The Specious Present: A Neurophenomenology of Time Consciousness. In J. Petitot. et al. (Eds.), *Naturalizing Phenomenology: Issues in Contemporary Phenomenology and Cognitive Science*. Stanford, CA. Stanford University Press.
- Varela, F. J. & Shear, J. (1999). First-person Methodologies: What, Why, How? In F. J. Varela & J. Shear J. (Eds.), *The View from Within. First-person Approaches to the Study of Consciousness*. Exeter, England. Imprint Academic.
- Varela, F. J., Toro, A., John, E. R., Schwartz, E. L. (1981). Perceptual framing and cortical alpha rhythm. *Neuropsychologia*, 19, 675-686.
- Velmans, M. (1991). Is human information processing conscious?. *Behavioral and Brain Sciences*, 14, 651-726.
- Vicario, G. B. (2005). *Il tempo. Saggio di psicologia sperimentale*. Il Mulino. Bologna.
- Vogeley, K. & Fink, G. R. (2003). Neural correlates of the first-person-perspective. *Trends in Cognitive Sciences*, 7 (1), 38-42.
- Vygotskij, L. S. (1973). *Problemy psichičeskogo razvitija rebenka*. (Italian translation, 1984: *Lo sviluppo psichico del bambino*. Roma. Editori Riuniti.).
- Ward, L. M. (2003). Synchronous neural oscillations and cognitive processes. *Trends in Cognitive Sciences*, 7 (12), 553-559.
- Wilkes, K. (1988). -, yìshì, duh, um, and consciousness. In A. J. Marcel & E. Bisiach (Eds.), *Consciousness in Contemporary Science*. Oxford. Oxford University Press.
- Wickens, C. D. (1984). Processing resources in attention. In R. Parasuraman & D. R. Davis (Eds.), *Varieties of attention* (63-102). New York. Academic Press.
- Zeman, A. (2001). Consciousness. *Brain*, 124, 1263-1289.

Chapter 3

ILLUSORY PERCEPTIONS AND MEMORIES: WHAT IS THE TIE THAT BINDS?

Timothy N. Odegard¹, James M. Lampinen² and Emily A. Farris¹

¹University of Texas Arlington, TX, US

²University of Arkansas, AR, US

ABSTRACT

Research suggests that both perceptual and memory representations involve discrete features that are bound together to form coherent wholes. The process which combines features into unified wholes is known as feature binding and is seen as an integral part of conscious experience. Errors occur in both perceptual and memory based feature binding. In perception, errors in feature binding produce illusory conjunctions. For instance, participants presented with a red triangle and a blue square will sometimes mistakenly perceive a blue triangle next to a red square. Illusory conjunctions demonstrate the importance of attentional resources in the binding of features in perception. Feature binding errors also occur in memory. Such errors are known as memory conjunction errors. For example, participants presented with words such as *blackmail* and *jailbird* will sometimes mistakenly remember the word *blackbird*. Such findings provide evidence for the reconstructive nature of human memory. Considerable research has established the existence and subjectively compelling nature of these sorts of errors. Moreover, relatively well established theoretical literatures exist in an attempt to account for both illusory conjunctions and memory conjunction errors. However, to date, no systematic attempt has been made to draw parallels and connections between these two literatures. The purpose of the present chapter is to demonstrate similarities and differences between these two types of errors and to provide a unified comprehensive account of both types of errors. In the process we hope to elucidate how feature binding can be used to better understand both perception and memory.

INTRODUCTION

Perception and memory are inextricably related to one another (Payne & Blackwell, 1998; Roediger, 1996). We must sense what is in our environment before we are able to encode a mental representation of this information into our memory. Likewise, our memory aids in our ability to perceive the world around us, allowing us to recognize objects, to complete obscured patterns and in short, make sense of the world. In fact, the interplay between the two is so great that it has been difficult to clearly distinguish between our reliance upon one over the other when performing certain tasks (e.g., Tsal, 1989; Treisman & Souther, 1986).

One established commonality shared between memory and perception is the reliance upon top down, inferential processing (Briand & Klein, 1989; Treisman & Schmidt, 1982). Both Bartlett (1932) and Kohler (1947) commented on the organization imposed on perception and memory by previous experience with the world and on how this organization aids us in perceiving and remembering aspects of our environment.

Consider for example, a series of experiments in which Bartlett (1932) presented participants with unfamiliar drawings of objects and later tested their memories. His participants often labeled the drawings with the names of something more familiar to them, thereby placing the objects into more familiar categories. Categorizing these unfamiliar objects improved his participants' abilities to remember them. Yet, Bartlett noted that this improvement came at a cost. Bartlett stated that labeling visual information "immediately shapes what is seen and what is recalled" (p. 20). For instance, participants often labeled one of the novel objects a *turf cutter*. Bartlett argued that this act of labeling led his participants to mentally alter the shape to correspond to the shape of a turf cutter. Subsequently, participants remembered this altered representation as opposed to the drawing that was actually presented at study.

Thus, past experience with the world skewed these participants' perceptions and memories for what was presented. Our semantic knowledge interacts with our present perceptions providing predictability and understanding to the world around us. Although Bartlett's participants often labeled the unfamiliar objects, they did not agree upon a single label for each of the objects. Consequently, participants perceived and subsequently remembered the drawings differently depending upon the labels used. More recent research (Bransford & Franks, 1972; Broadbent & Broadbent, 1978) has emphasized the importance of context in guiding our perceptions and our memories.

As Bartlett's research demonstrated, perception and memory are highly organized and influenced by top down processing (Hannigan & Reinitz, 2003; Schank, 1982). There is more to cognition than the mere sum of its parts, and our phenomenology of the world is far richer than the physical energy in the world that we are endowed to detect. An appeal to inferential processing provides an account for why individuals are motivated to include certain details that were not presented in their perceptions or memories, but top-down processing cannot fully account for the coherence with which we perceive and remember the world around us (Reyna & Lloyd, 1997). For example, in contrast to a straight constructivist account of memory, individuals are able to perceive and remember objects regardless as to whether or not they are capable of identifying and labeling them (Kahneman & Treisman, 1984;

Kahneman, Treisman, & Burkell, 1983; Treisman, 1992; Treisman, Kahneman, & Burkell, 1983; Treisman & Paterson, 1984).

To account for this ability, some researchers have suggested that our perceptual system is designed to experience the world as discrete pieces of information, typically referred to as features (Cavanagh, Arugin, & Treisman 1990; Treisman & Gelade, 1980; Cave & Wolfe, 1990; Wolfe & Cave, 1999; Wolfe, Cave, & Franzel, 1989; Zeki & Shipp, 1988). Considerable evidence suggests that objects are parsed into basic feature representations that are processed in different areas of the brain, or at least by different cells within the same area of the brain (Ashbridge, Cowey, & Wade 1999; Mishkin, Ungerleider, & Macko, 1983; Van Essen & Maunsell, 1983). The conundrum of exactly how discretely processed features become represented as a coherent whole, maintaining the various relationships shared between the different aspects of the environment is referred to as the binding problem. Many see the binding problem as being central not only to memory and perception but to consciousness itself (Singer, 2001).

The binding problem often has been discussed in terms of perceptual processing, but cognitive processes, such as decision making and memory, also rely on the binding of discrete pieces of information into a single psychological event. Roskies (1999) imposed a useful distinction between perceptual and cognitive binding, acknowledging that higher order cognitive processes also rely on feature binding. For example, most models have conceived of memories as being composed of discrete features (e.g., Metcalfe, 1990; Moscovitch, 1994; Schacter, Norman, & Koutstaal, 1998). Yet, our memories are experienced as bound representations of past events or previously learned knowledge. Consider, for example, episodic memories. A person is capable of reliving the experience of graduating from college, including the different aspects that were present during the event (e.g., music, people, smells). Although the aspects composing the episodic memory are processed in different cortical areas, the person recalls them as belonging to the same memorial event (Tulving, 1983). This seemingly simple ability to form associations between information presented in the environment illustrates that the binding problem is just as real for memory as it is for perception (Eichenbaum, 2000; Eichenbaum & Bunsey, 1995).

Given the relationship shared between perception and memory, it seems likely that an understanding of perceptual binding may provide a basis to understand memorial binding. A considerable amount of research has investigated perceptual binding (see Prinzmetal, 1995; Wolfe & Cave, 1999 for reviews). In particular, illusory conjunctions have been used to better understand feature binding. An illusory conjunction occurs when a person inappropriately binds together features from two separate objects to form a novel object (Ashby, Prinzmetal, Ivry, & Maddox 1996; Chastain, 1982; Khurana, 1998; Prinzmetal & Millis-Wright, 1984; Treisman & Schmidt, 1982). For example, a participant simultaneously presented with a red *T* and a green *L*, may report seeing a green *T*. Such errors are perceptual illusions and evoke the subjective experience of actually seeing the composite object. Given the resurgence of interest in memory illusions (Koriat, Goldsmith, & Pansky, 2000; Lampinen, Neuschatz, & Payne, 1998; Roediger & McDermott, 1995; Schacter, 2001), the adaptation of procedures and logic from the perceptual literature to the investigation of memory illusions may prove to be a useful way to explore how perceptual and memorial binding are related.

For the purposes of the present discussion let us focus on memory conjunction errors, an error analogous in many respects to illusory conjunctions. Like illusory conjunctions, memory conjunction errors occur when aspects from two different memorial events are

misremembered as having occurred in the same event (Reinitz, Morrissey, & Demb, 1994). Also, there is research suggesting that memory conjunction errors, like illusory conjunction errors, are accompanied by the phenomenology of being real (Reinitz & Hannigan, 2004; Reinitz, et al., 1994; Odegard & Lampinen, 2004). In addition, top-down processing can constrain the formation of both illusory conjunctions and memory conjunction errors. Finally, many of the independent variables that have been demonstrated to influence the occurrence of illusory conjunction also have been demonstrated to influence the occurrence of memory conjunction errors (e.g., distance, similarity). This high level of functional concordance between illusory conjunctions and memory conjunction errors suggests that similar processes may be involved in the two types of illusions.

Given that illusory conjunctions have enhanced the understanding of perceptual binding, a better understanding of memory conjunction errors will provide a testing ground for the role of features and feature binding in memory. In particular, such an understanding will provide a representational framework from which to better understand dual process models of memory that appeal to the concepts of recollection and familiarity (Jacoby, 1991; Mandler, 1980). As will be argued, ideas put forth from a binding perspective of memory mesh well with some of the original accounts of recollection and familiarity. Also, a binding perspective provides a compelling account of other illusory memories and the decline of veridical memories across time.

PERCEPTUAL FEATURE BINDING

Basic perceptual features are the building blocks of perception and are processed with minimal cognitive effort (Prinzmetal, 1981). For example, it is commonly held that colors (e.g., red) and basic shapes (e.g., vertical lines) are basic perceptual features (Khurana, 1998; Prinzmetal & Millis-Wright, 1984; Treisman & Schmidt, 1982). However, it has been suggested that through experience more complex objects comprised of multiple simple shapes (e.g., right angle) and even symbols (e.g., letters, words) can take on characteristics of basic perceptual features (Estes, Allmeyer, & Reder, 1976; Mozer, 1983; Prinzmetal & Mills-Wright, 1984; Treisman & Souther, 1986; Virzi & Egeth, 1984; Wolford, 1975).

These inconsistencies make it difficult to identify exactly what is and is not a basic perceptual feature. As a result, Treisman and Paterson (1984) stressed that perceptual features were not to be defined *a priori* based on assumptions of what constituted a basic perceptual component or strictly in regards to neural representations but were to be empirically validated. They outlined three criteria for the acceptance of a dimension as a basic perceptual feature. First, a feature is basic if it can be processed at a preattentive level. Thus, a person should be capable of processing basic features in parallel. Second, visual features allow for texture segregation. Individuals should be capable of preattentively parsing the world in regards to basic perceptual features (e.g., red versus green). Finally, when attention is taxed or diverted, features are not adequately bound together allowing for the formation of illusory conjunctions within scenes composed of objects containing multiple features.

Let us consider the first two criteria, before discussing illusory conjunctions. In contrast to Gestalt Psychologists, Treisman and Gelade (1980) suggested in their feature integration theory (FIT) that individuals are capable of processing the constituent features of an object

prior to processing the gestalt of the object (see also, Cavanagh, et al., 1990; Cave & Wolfe, 1990; Wolfe & Cave, 1999; Wolfe, et al., 1989; Zeki & Shipp, 1988). This results from the individual features of an object being processed prior to the onset of directed attention. In FIT terms directed attention results in the binding of features into an object representation (Kahneman & Treisman, 1984; Kahneman, et al., 1983; Treisman, et al., 1983; Treisman & Paterson, 1984). Thus, the object is not assembled until a person has had ample time to attend to it. This would suggest that individuals should be capable of searching for and reporting the presence of individual features (e.g., the hue red or a vertical line) more quickly than searching for and reporting the presence of a conjunction of multiple features (e.g., a red vertical line). Engaging in a conjunctive search requires additional time for directed attention to process object representations for information presented in a visual scene.

To investigate this prediction, Treisman and Gelade (1980) manipulated the conjunctive nature of the information that they asked their participants to search for in a visual field. For feature search trials, participants were asked to search for the presence or the absence of two features (e.g., find something red and find a vertical line). For conjunctive search trials, participants were asked to search for objects containing both features (e.g., find a red vertical line). The number of features being searched for was identical in both conditions, but still it took participants longer to perform conjunctive searches than feature searches. Treisman and Gelade concluded that it was not merely the number of features being searched for that determined the amount of time that it took to search a visual field. Rather, it was the conjunctive nature of the sought after information that increased the search time between the two conditions. Presumably, individual features could be searched for in parallel, decreasing the amount of time needed to identify multiple features when conducting a simple feature search.

An important addition to FIT was made by Wolfe et al. (1989) in their theory of Guided Search. They suggested that searches for simple features that compose a complex object continually update and inform conjunctive searches. Additionally, they made the counterintuitive prediction that engaging in a conjunctive search for objects containing three required features would take less time than engaging in a conjunctive search for objects containing only two required features. As predicted, their participants took less time to search for objects containing conjunctions of three features as opposed to objects containing conjunctions of two features, providing evidence for the first and second criteria established by Treisman and Paterson (1984). By the first criterion features are processed in parallel and by the second criterion features allow for texture segregation. Wolfe et al. interpreted their findings to suggest that participants were able to parse the visual field into coarse sections and guide the focus of attention to those sections that were most likely to contain a target match. In the three feature condition, the information provided by the third feature allowed for the search to be more fully refined, than that of the search established in the two feature condition. Further refining the search through the use of the third feature did not take any longer because the feature was processed in parallel with the other two features.

These early results provide an initial concept of what constitutes a basic perceptual feature. Indeed it appears that there are dimensions along which individuals can process information in parallel (e.g., shape and color). Additionally, it appears that features allow for a coarse coding of the environment into different areas, allowing individuals to refine their searches. Let us now turn to the research investigating illusory conjunctions to further understand the role of binding in the formation of our perceptions of the world. Also, research

investigating illusory conjunctions helps us to understand organizational principles that determine exactly how perceptual information will be parsed in the environment. The manner in which the environment is parsed constrains the formation of illusory conjunctions. In particular, the investigation of illusory conjunctions provides a fuller understanding of the role played by top down processes in determining what constitutes a feature. This point is of particular interest to memory research because memory conjunction errors do not typically involve such basic components as lines or colors. Rather, memory conjunction errors typically involve entire objects, such as facial features (Hannigan & Reinitz, 2000), words (Jones & Jacoby, 2001; Kroll, Knight, Metcalfe, Wolf, & Tulving, 1996; Reinitz, et al., 1994; Underwood, Kaplek, Malimi, 1976), or even people, places and activities (Hannigan & Reinitz, 2003; Odegard & Lampinen, 2004).

Illusory Conjunction Errors

Support for the existence of basic perceptual features and feature binding has been sought through the investigation of illusory conjunctions. Occasionally when participants view a scene they will errantly bind together features from different objects, forming the perception of objects that were not actually presented in the visual scene. This often occurs when attention is divided or overloaded. Such errors are referred to as illusory conjunctions and are viewed as compelling evidence for the assertion that information is processed at a basic feature level prior to being processed at a holistic level. Some theories have argued that illusory conjunctions are capable of being produced solely by errors in perceptual processing (Treisman & Schmidt, 1982; Wolford & Shum, 1980). In other words, the creation of illusory conjunctions need not depend upon top-down processing. However, because of the importance that we assume top-down processing to play in memory binding, we will discuss in detail the role that top-down processing can play in constraining the formation of illusory conjunctions.

Illusory conjunctions are termed illusory in that they are experienced as compellingly real, when in actuality they are distortions of what is really being presented in the environment. In accordance with this phenomenology, participants often report high levels of confidence in their accuracy when reporting them (Treisman & Schmidt, 1982; Treisman & Souther, 1986). Additionally, participants feel compelled to report illusory conjunctions. For instance, in one experiment participants spontaneously reported experiencing illusory conjunctions. For this experiment, Treisman and Schmidt informed their participants that a series of numbers printed in black ink would be presented and asked their participants to report the digits as they were presented. Each of the digits was flanked by a color. Quite surprisingly, several participants spontaneously reported that something must be wrong or have changed in the procedure because some of the digits were being presented in colors other than black. Presumably participants were errantly binding the flanking colors and the digits together to form illusory conjunctions. Such an impressive result suggests that participants indeed experienced these errors in an illusory sense (see Prinzmetal, 1981 for similar observations).

In addition to being illusory in nature, illusory conjunctions can be the product of purely perceptual processing as opposed to memory errors (Treisman & Schmidt, 1982; Wolford & Shum, 1980). Items typically used in illusory conjunction experiments are target, conjunction

and feature object probes. Target object probes exactly correspond to an object presented in a visual display. Conjunction object probes are composed of features that were presented in objects in a display, but these features were not presented in a single object within the visual display. For example, a color from one object presented in the display might be combined with a digit presented in another color within the display to form a novel color digit combination. Thus, the features composing a conjunction lure probe were both presented, but they were not presented in the same object within the display. Feature object probes are novel combinations of a feature that was presented in a visual display, with another feature that was not presented in the visual display. Falsely accepting a feature probe as having been presented in a visual field is not caused by errantly combining two presented features to form an illusory conjunction. To assume that the false acceptances of conjunction objects are due to errant perceptual binding, participants must falsely accept significantly more conjunction than feature objects (Hazelton, Prinzmetal, & Elliot, 1997; Treisman & Schmidt, 1982).

In one of the most commonly used procedures, participants are presented with a visual scene containing multiple objects. Immediately following the presentation of the scene, participants are presented with a probe object. In some cases the probe object is a target, in others a conjunction and in others a feature. They are asked if the probe object was shown to them. Participants typically report having seen conjunction objects more often than having seen feature objects. Although the probes are presented immediately after the presentation of the visual scenes, this task is in essence a recognition memory test, requiring participants to match the probe object against their memory for all of the objects just presented in the visual scene.

Treisman and Schmidt (1982) had participants in their second experiment perform a matching task, in an attempt to provide more compelling evidence that illusory conjunctions are indeed perceptual and not memory illusions. Prior to being shown a display, participants were shown a card containing a probe object and were asked to search for that object in the upcoming visual scene. Even under these conditions, participants indicated having seen the conjunction probes in the visual scene and did so more often than reporting having seen feature probes. Although participants still rely upon their memory for the probe object, participants only have to hold a representation of a single object in mind while viewing the scene. These results provide compelling evidence that illusory conjunctions can be the product of purely perceptual processing.

However, a simultaneous matching task used by Treisman and Schmidt (1982) in their third experiment completely eliminated reliance on memory. For this procedure participants were presented with a visual scene containing five colored letters and were asked to determine if any of the letters presented within the display exactly matched one another. If two identical letters were presented in the same color, participants were required to respond "same." If none of the same letters were presented in the same color, participants were required to respond "different." Unlike the probe matching tasks, this technique requires no memory processing. Also, this technique does not require participants to provide verbal labels for their perceptions, further refining the investigation strictly to perceptual processing. Even under these conditions participants still misreported seeing two identical letters presented in the same color even when two such letters were not present in the display.

The above research provides strong evidence for the perceptual and illusory nature of illusory conjunctions. They also make evident the importance of careful interpretation of the results of such studies. Before we can say with confidence that illusory conjunctions are

occurring, a set of criteria must be met. First, to conclude that illusory conjunctions are the product of perceptual and not memorial processing, we must determine that people are not guessing. Second, a person must perceive the features in a visual scene. If this requirement is not met, participants may engage heedlessly in guessing. Third, features must be *free floating*, allowing them to be inaccurately bound together. We will discuss exactly how free features are to float throughout an entire visual display in some detail, but the point to be made is that features should not be bound into object representations. Finally, the task must be devoid of constraints from top-down processing for illusory conjunctions to be completely arbitrary.

Let us consider the first criterion. Individuals should not be binding into their perception what might have been on the screen, but rather, participants should be inappropriately binding together features that were presented in the visual scene. Thus, there is traditionally a comparison of conjunction errors to feature errors. Conjunction errors are the inaccurate combination of two features presented in a single visual field. In contrast, feature errors are the inaccurate combination of one presented and one non-presented feature. To the extent that features presented in the visual field bias people's perceptions, this suggests that on-line perceptual processes are responsible. To the extent to which people falsely acknowledge the presentation of a feature object, this suggests that they are guessing or are being influenced by their memories for features from an earlier presented visual scene. Conjunction errors are typically more common than feature errors.

Prinzmetal and Millis-Wright (1984) made the point that multiple processes could lead to the same behavioral response even more explicit. They did not use the term illusory conjunction when referring to any one behavioral response. Instead these researchers referred to off feature errors and on feature errors. Off feature errors occur when participants report the presence of an object that contains one feature that was presented and one feature that was not presented. On feature errors are the inappropriate reporting of an object that contains two features from a visual display in the wrong relationship to one another. Off feature errors can only occur because of memory errors or guessing but not the inappropriate binding of two presented features. However, in addition to memory and guessing, on feature errors can occur because of the inappropriate binding of two presented features to form the perception of an object.

To account for the overlap of processes, Prinzmetal and Millis-Wright (1984) introduced equation 1 to obtain the approximate proportion of responses that were the product of illusory conjunctions, or inappropriate binding.

$$P_{conj} = \left[\frac{on_{error}}{on_{error} + off_{error}} - E_{(on)} \right] \quad \text{Equation 1}$$

In equation 1 $E_{(on)}$ represents the probability of guessing the presence of a feature in the field but reporting it in the wrong object. For example, a person may be presented with a series of letters that include a red *O* and a green *T*, but the person reports a green *O*. A person may not have perceived the color green, but rather simply guessed that green was present and reported it as having seen a green *O*.

Equation 1 is included because it is illustrative of the combinatorial nature of processes that can give rise to the same behavioral response. The equation further stresses the need to

access the presence or absence of illusory conjunctions by comparing different classes of behavioral responses, opposed to simply accepting a single class as definitive evidence. It is not included because it provides an accurate estimate of illusory conjunctions, nor of the binding process. In fact, because the guessing parameter used is often too large, it most likely does not provide an accurate estimate (Prinzmetal & Millis-Wright, 1984). However, see Ashby et al (1996) and Prinzmetal, Ivry, Beck, & Shimizu (2002) for discussions of more formal techniques for measuring illusory conjunctions and latent cognitive processes potentially underlying them.

The second criterion that must be met to ensure that illusory conjunctions are the result of perceptual processing is that a person must perceive the features presented in a visual scene. If this requirement is not met, participants may engage heedlessly in guessing. For example, in their fifth experiment, Treisman and Schmidt (1982) reduced the ability of their participants to fully process the features presented in a visual field by limiting the rate of exposure. Under such conditions, participants were just as likely to commit feature errors, as they were to commit conjunction errors. Although this guessing may be constrained to plausible errors, such results suggest that illusory conjunctions necessitate the processing of basic features.

Third, features must be *free floating*, allowing them to be inaccurately bound together. Features are processed at a basic level requiring very little cognitive capacity. While there is not a consensus on exactly how binding occurs, the binding of individual features into a single object representation requires additional cognitive capacity. When attention is divided or presentation speeded, features are not bound together and are thought of as *free floating* (Treisman & Schmidt, 1982; Wolfe et al, 1989). When participants are forced to provide a response in such instances, *free floating* features can become inaccurately bound to one another resulting in an illusory conjunction.

In a related point, the task must be devoid of constraints from top-down processing for illusory conjunctions to be completely arbitrary (Hazelton, et al., 1997; Prinzmetal et al., 2002). However, the line between bottom-up feature based and top-down processing is a precarious one indeed (e.g., Beck & Palmer, 2002), requiring great care be taken to ensure the exact nature of illusory conjunctions. When such care is not taken, participants will respond based on presumptions as to what could have or should have been present. For example, if presented with an outline of an apple, a person may assume that it was filled with a red hue, regardless as to whether or not a red hue was presented in the visual display. One way to control for expectancy effects is to use materials devoid of as much meaning as possible. Illusory conjunctions observed by Treisman and Schmidt (1982) were the product of materials that were assumed to be unrelated to one another. Yet, even in cases in which seemingly meaningless materials are used, participants do not produce responses that violate basic rules that were used to construct the materials (e.g., Wolford & Shum, 1980), suggesting that even in these cases responses are being curtailed by expectancies set by the testing environment.

Constraining Illusory Conjunctions

Inferential processing can not completely account for our perception of the world. As evidence for this assertion, we cited the capability of individuals to perceive information

regardless of having previously experienced it. Although we ourselves setup this distinction and Treisman and Schmidt (1982) argued against the holistic perspective of the gestalt psychologists, feature analysis is influenced by organizational principles. Characteristics of the visual environment constrain the formation of illusory conjunctions, and research suggests that some order is present preattentively. This order biases exactly how illusory conjunctions are formed. If illusory conjunctions can be biased, what then are the unifying aspects of the visual environment that give rise to the formation of illusory conjunctions?

To answer this question we must examine the commonalities shared between variables that constrain the formation of illusory conjunctions. It appears that features are constrained in that they are bound to general areas of the visual environment. For instance, features have been found to stay confined within words, syllables, groups of objects formed using good continuation, and objects that look similar to one another. Thus, features may not be as free to float around as had been originally proposed by Treisman and her colleagues. One of the reasons that features become regionally bound is because of the level at which individuals parse the environment. Even when information is presented fairly quickly individuals are still capable of parsing visual information based on general principles.

Temporal Contiguity or Spatial Proximity

Several, simple aspects of the environment constrain the formation of illusory conjunctions. Both temporal contiguity and spatial proximity have been suggested to underlie the binding of features into object representations (Crick, 1984; Gathercole & Broadbent, 1984; Keele, Cohen, Ivry, Liotti, & Yee, 1988; McLean, Broadbent, & Broadbent, 1983). Crick (1984) suggested that temporal contiguity is important for binding together features because perceptual information is temporally marked as it passes through the thalamus. However, others have argued that spatial proximity rather than temporal contiguity is important in binding together features (Ashby et al. 1996; Gathercole & Broadbent, 1984; McLean, et al., 1983; Prinzmetal et al. 2002).

By directly pitting temporal and spatial proximity against one another, McLean et al. (1983) and Gathercole and Broadbent (1984) provided evidence that spatial location was more important than temporal proximity for increasing rates of illusory conjunctions. Participants in their experiments viewed digits presented very quickly one right after the other. Embedded within this series of digits was a letter. These researchers manipulated the temporal proximity of features to one another and whether or not features shared the same location on the screen. They predicted that illusory conjunctions would be most likely to occur between the letter and the colors from digits presented in the same location. Specifically, they manipulated whether or not the digit +1 or -1 positions from the letter was in the same or different location as the letter. They also manipulated whether or not the digit +2 or -2 positions from the letter was in the same or different position as the letter.

Participants were required to report the color of the letter presented embedded within the series of digits. The spatial location of the digits on the screen varied from the left to the right of the fixation point located in the center of the screen. This allowed the researchers to manipulate whether or not the digit and the letter shared the same spatial location. These researchers were interested in the rate at which participants reported an illusory conjunction of the letter and the color from one of the digits surrounding it in the list. If temporal

proximity determines binding, as suggested by some, then participants should be more likely to form illusory conjunctions using the color from the digit +1 or -1 positions from the letter. These errors should occur regardless of whether or not the digit is located in the same or different positions as the letter.

However, participants were more likely to form illusory conjunctions using the color from a digit +2 or -2 positions away from the letter when the digit and letter were presented in the same location, than they were to form illusory conjunctions using the color from the digit presenting +1 or -1 positions away from the letter when the letter and digit did not share the same spatial location on the screen. These results suggest that features from the same spatial location are more likely to be errantly bound together than are features that are presented close together in time but in different locations (see Keele, et al 1988 for similar results).

Unfortunately, these results do not generalize to the overall importance of spatial proximity in the formation of illusory conjunctions because they merely demonstrate that features presented in the exact same location are more likely to be bound into illusory conjunctions. Also, the features used to form these conjunction errors were not presented on the screen at the same time, increasing the role of memory in the formation of such errors. Yet, past research has demonstrated that illusory conjunctions are more commonly formed using features that are presented closer together in a single visual display (Ashby et al., 1996; Chastain, 1982; Hazeltine, et al., 1997; Wolford & Shum, 1980).

Hazeltine et al. (1997) manipulated the distance that simultaneously presented features were from one another. These researchers presented a row of five letters across the center of the visual display. In the first experiment, participants were asked to report the presence or absence of a green *O*. Participants were presented with target displays, which contained a green *O*. They were also presented with feature and conjunction displays. Feature displays contained a green letter but did not contain an *O*. Conjunction displays contained an *O* that was not green and another letter other than an *O* that was green. For half of the conjunction displays the green letter and the *O* were presented adjacent to one another in the array with no intervening letter between them (near condition). For the remaining conjunction displays, an intervening letter was present in between the *O* and the green letter (far condition). Thus, these researchers effectively manipulated the distance between the two features needed to form an illusory conjunction. As predicted if spatial proximity underlies the binding of information, almost twice as many conjunction errors were reported for the near conjunction displays than for the far conjunction displays.

These results demonstrate the importance of spatial proximity in the creation of illusory conjunctions, but one of the limitations of Hazeltine et al's (1997) findings is that distance was confounded with the presentation of an intervening letter between the green letter and the *O* in conjunction displays. Ashby et al. (1996) manipulated the distance that features were from one another within a visual display in a manner that avoided this confound. For their design, they presented participants with an array that contained a fixation point in the center of the display and a pair of letters was presented in one of the four corners of the display. The pair of letters was surrounded by *S*s, which past research had demonstrated to enhance the number of conjunction errors committed for such materials (Treisman & Schmidt, 1982). The target letters never were presented in the same pair. Instead these target letters were paired with distractor letters, either a *C* or an *S*. The target and distractor letters within a pair were

presented in different colors. Participants were required to report the presence and color of target letters (i.e., Ts and Xs).

These researchers manipulated the distance between the target and distractor letters within a pair, either near or far. The question of interest was how often participants would inaccurately report that the target letter was presented in the color of the distractor letter and whether or not this effect would be moderated by the distance between the letters. As predicted, target letters were reported to have been presented in the color of the distractor letter more often when the distractor letter was presented closer to the target letter. These results demonstrate illusory conjunctions to be more common between features that are presented closer together, suggesting that location is an important factor underlying feature binding.

Although these results are compelling, other variables have been found to influence the formation of illusory conjunctions. For example, Prinzmetal (1981) found that organizing features into groups using good continuation resulted in more conjunction errors than merely placing features spatially close to one another. Participants in this study were presented with visual displays containing eight circles. These circles were presented such that four of the circles formed a straight line of circles with very little space separating one circle from the other. The remaining four circles formed another line. These groups of circles ran parallel to one another, and the distance separating them was roughly equivalent to the diameter of one of the circles. In addition to circles, vertical lines, horizontal lines and crosses were presented within two of the circles. The task was to report the presence or absence of a cross. For target displays, a cross was placed inside a circle and either a vertical or horizontal line was placed inside one of the other circles. For conjunction displays, a cross was not presented in any of the circles but a vertical line was placed in one circle and a horizontal line was placed in another. For feature displays, only horizontal lines or only vertical lines were placed in the display.

The distance between the vertical and horizontal lines and crosses was held constant in the display, what varied was whether or not these features were placed in the same or different groups of circles. Again participants were required to report whether or not a cross was present in the visual display.

More conjunction errors occurred when the vertical and horizontal lines were presented in the same group of circles as opposed to different groups of circles. Similar results were found in the fourth experiment in which color as opposed to distance was used to distinguish one group of circles from the other. For this experiment, four of the circles were positioned next to one another and colored yellow. The other group of circles was colored pink.

Also, of note is that for these materials the groups of circles ran directly into one another such that the last circle in the pink group was just as close to the first circle in the yellow group as it was to the closest circle in its own pink group. Even when the features needed to form the illusory conjunction of the cross were adjacent to one another, features from the same group (i.e., the same color) were more likely to be inappropriately bound together forming an illusory cross than features from different groups (i.e., different colors). These results stress that there is more to binding than merely how close features are to one another.

ROLE OF SIMILARITY

Good continuation is not the only grouping principle that influences illusory conjunctions. Similarity also influences the formation of illusory conjunctions. Ivry and Prinzmetal (1991) observed that features within similar objects were more likely to be bound together than features within objects that were more dissimilar to one another. In their first experiment, they presented pairs of letters that were either displayed in similar or dissimilar colors (e.g., red and orange, green and blue versus red and green, blue and orange). Letters presented in similar colors were more likely to have their constituent features inappropriately bound together forming conjunction errors than letters presented in dissimilar colors. For example, when presented with an orange *M* and a red *T* participants were more likely to form an illusory conjunction (e.g., red *M*) than when presented with a red *M* and a green *T* (e.g., green *M*).

In their second experiment, Ivry and Prinzmetal (1991) manipulated the similarity shared between the two letters presented in a visual display and measured the proportion of illusory conjunctions formed between color and letter. In the similar letter condition, participants were presented with *T* and *L* or *M* and *U*. Participants were more likely to form illusory conjunctions, inappropriately binding the colors from similar letters than dissimilar letters. Thus, in addition to all of the other principles that have been identified to constrain the formation of illusory conjunctions, the similarity shared between different objects also constrains their occurrence.

Moreover, linguistic principles also influence the level at which participants parse the environment. Word processing has been found to bias the formation of illusory conjunctions. For example, features are more likely to be interchanged between aspects within a single word than between other words (Prinzmetal & Keysar, 1989; Prinzmetal, Treiman, & Rho, 1986). Also, features are more likely to be interchanged within a syllable of a word as opposed to between syllables.

An interesting question that has been addressed by some researchers is whether or not semantic meaning is a feature that can be inaccurately bound to form illusory conjunctions. This point is of importance to memory researchers because both perceptual and semantic similarity has been found to result in recognition memory errors. As such, any feature account of memory must be able to handle both perceptual and semantic qualities of a memory event.

Within the illusory conjunction literature there is an interesting result obtained by Virzi and Egeth (1984). These researchers observed participants to occasionally form illusory conjunctions involving colors and shapes by errantly binding in a color whose hue was not presented but whose linguistic representation was presented (e.g., the word *red*). These errors were rare but illusory conjunction errors of this sort occurred more often than feature errors.

Summary of Illusory Conjunctions

All of these environmental constraints are highly relevant to memory conjunction errors, because memory conjunction errors often involve complex objects or words. On this point, research has demonstrated what have been empirically validated as multiple basic perceptual features acting as a single feature representation. For instance, letters are composed of

multiple simple shapes, but it has been demonstrated that letters presented in different words can migrate and recombine to form illusory conjunctions of words not presented in a visual array (Mozer, 1983; Treisman & Souther, 1986).

Also, understanding the role played by similarity in illusory conjunctions is important because similarity has been used to account for memory conjunction errors (Jones & Jacoby, 2001). What an appreciation of the perception literature reveals is that binding errors and similarity processes are not orthogonal to one another. This distinction has been presupposed in much of the memory literature.

The oddball result among all these is the importance of the same location in the formation of an illusory conjunction (Gathercole & Broadbent, 1984; McLean, et al., 1983) because it is more akin to a memory conjunction error than an illusory conjunction. The features making up the conjunction error were not presented simultaneously but were separated across time. Indeed this procedure is very similar to those that have been used to form memory conjunction errors. However, the memory conjunction literature has yet to disambiguate the influence of location and temporal contiguity.

Before turning our attention to memory conjunction errors and cognitive binding, we must first attend to the understanding of perception and feature binding that has been garnered from the vast amount of research that has been conducted on illusory conjunctions. First, perception can be reduced to a basic level, but the level at which we process the world is determined by organizing principles. Also, the level of analysis can be primed by the testing environment.

The bottom line is that all of the variables reviewed above influence the parsing of the environment into groups of objects. Objects that are closer together in a visual display are more likely to be perceived as a group. Objects that form a line through good continuation are not only close together but form a recognizable pattern. Those letters that form a word are more likely to be processed as a unit. Within a single word those letters that form a syllable are more likely to be processed as a unit. These units help to guide our attention within a visual display and determine which features are most likely to be coarsely grouped together and potentially inappropriately bound together.

Yet, the overall question still remains. What is the root cause of illusory conjunctions? Given the extant literature, illusory conjunctions occur when the location information for features is represented at a “fuzzy” level (Ashby et al., 1996; Prinzmetal et al., 2002). Consider that speed of presentation must be very rapid or participants’ attention must be divided in order to observe illusory conjunctions. Due to this lack of information the binding process must rely on insufficient information and in such instances supplementary information from organizational principles is more heavily relied upon. Then what is the root cause of memory conjunction errors? Potentially they too are caused by fuzzy representations of the past.

COGNITIVE FEATURE BINDING

Researchers investigate illusory conjunctions in an attempt to better understand the functioning of our perceptual system as a whole. Taxing the boundary conditions of the perceptual system gives rise to illusory conjunctions, and these errors provide a glimpse into

the processes underlying perception. Likewise, investigating memory illusions provides a better understanding of processes underlying memory. In the present chapter, the accuracy of our memories is not of central concern. Instead, we are interested in the extent to which discrepancies, between what a person remembers occurring and what actually occurred, can help us to better understand memory as a whole. Memory illusions, by and large, do not represent memory pathology. Rather, as Schacter (2001) argued, memory illusions are a normal consequence of memorial processing.

Memory Conjunction Errors

Memory conjunction errors are distorted memories containing details from different past events. For example, consider an assault victim's memory for the details associated with the crime committed against her. After the incident she was asked to identify the perpetrator in a line-up. At that time, she identified who she thought was the perpetrator. The case went to trial, and the identified man was prosecuted. Several years later, DNA evidence exonerated this man. Although his innocence was demonstrated, the survivor of the assault claimed that every time she closed her eyes and remembered the event, she saw the face of the man she identified in the line-up assaulting her. She did not see the face of the man who was eventually convicted of the crime. The evidence suggests that this memory is a distortion of what actually happened, making it an extremely vivid false memory.

There is every reason to believe that a great many psychological factors contributed to the formation of this false memory. Yet, just as we have to account for the ability of the mind to bind together discretely processed features to form an illusory conjunction, we also have to account for the ability of the mind to bind together discretely processed memorial features to form a memory conjunction error. Thus, memory conjunction errors are important to the current discussion because they may arise from faulty feature binding.

From a feature binding perspective, memory conjunction errors occur when discrete features from multiple memorial events become inappropriately bound together. In the present example, consider the details from an event as being features. Stored in the woman's memory were features from the assault (e.g., clothing, smells, face, height, hair color, fear, etc.). Also stored in the woman's memory were details from the line-up, including the man's face that she identified. Inappropriately binding together features from these two events would produce a false memory in the same manner that many researchers propose illusory conjunctions to be formed. When considering this possibility, it is important to recall that the term illusory conjunction was applied to those perceptual errors resulting from the errant binding of perceptual features. An extension of this logic to memory requires that the term memory conjunction error be applied to only those errors occurring when memorial features are inappropriately bound together.

To more fully appreciate this logic, consider a commonly used procedure in this paradigm that utilizes recognition memory tests. In a typical memory conjunction experiment, participants are presented with study materials and later required to complete a recognition memory test comprised of targets, conjunction lures and feature lures. A target directly corresponds to a studied item. In contrast, a conjunction lure does not correspond to a single studied item. Instead, a conjunction lure is composed of features that were presented in two different studied items. For example, a participant might be presented with *blackmail* and

jailbird at study and later might be presented with *blackbird* on a recognition memory test. *Blackbird* was not presented at study, but both words (i.e., features) making it up were presented. Like conjunction lures, feature lures were not presented at study, but they are made up of one feature that was presented at study and another that was not. For example, say that *blackmail* was presented at study, and *blackbird* is presented at test. The test item as a whole was not presented at study nor was the feature *bird*, but the feature *black* was presented at study. Finally, foils are included on the test to provide a baseline rate of guessing on the memory test. Foils were not presented at study and neither were any of their constituent features.

Participants typically accept more targets than any other item type. Additionally, they accept more conjunction lures than feature lures and foils, and participants accept more feature lures than foils (i.e., TARGET > CONJUNCTION > FEATURE > FOIL). Similar to illusory conjunctions, if inappropriate binding occurred, it would only result in the acceptance of conjunction lures and targets. For instance, a person could remember all of the features that were presented in two different events (e.g., *black*, *mail*, *jail*, *bird*). Yet, they may not recall how these features were put together originally. There are two possible outcomes in our example. First, a person might combine the features to form a target (e.g., *blackmail*), resulting in the acceptance of a target on the recognition memory test. Second, they might combine the features to form a conjunction lure (e.g., *blackbird*), resulting in the acceptance of a conjunction lure on the recognition memory test. Both of these responses were born out of memory conjunction errors, even though one of the responses behaviorally represents an accurate memory, while the other response behaviorally represents a false memory. To better appreciate this example, consider the potential role played by feature and configural memory traces in our memories for past events.

The Role of Feature and Configural Memory Traces

One popular version of the feature binding account appeals to the encoding of feature and configural representations for a memorial event (Reinitz & Hannigan, 2001; Reinitz, et al., 1994). Feature traces represent the individual features that were present during an event. The configural trace contains information for exactly how these various features relate to one another. In essence, it is a kind of blueprint. When the configural trace is gone, there is no record of how the feature traces related to one another within an event. In addition, the configural trace would be unavailable to indicate that the feature traces from a past event even constitute a separate event memory. Thus, in the absence of a configural trace, a person must rely on other information to place feature memories in relationship to one another when compelled to remember the past. In such instances, a person may or may not replicate relational information accurately. As the previous example highlights, when relational information is replicated correctly, the resultant memory will be accurate. However, when relational information is replicated incorrectly, the resulting memory will be inaccurate. To entertain this understanding of memory, feature and configural representations must be empirically demonstrated.

In this respect, there is evidence that our memories, like our perceptions, are processed at a basic feature level. First, the retrieval of a memory produces activation across many different cortical areas. For instance, remembering visual details for a past event correlates

with activation in the occipital lobe (Gonsalves & Paller, 2000; Kosslyn, 2005; Kosslyn & Thompson, 2003; Kosslyn, Thompson, Kim, & Alpert, 1995). Likewise, recalling auditory information correlates with activation in the temporal lobe (Noppeney & Price, 2002; Wheeler, Petersen, & Buckner, 2000). Additionally, several researchers have demonstrated that accurate performance on a recognition memory test can be predicted by the amount of activation across several different cortical areas (Garoff, Slotnick, & Schacter, 2005; Gonsalves & Paller, 2000; Kosslyn, 2005), suggesting that a single representation does not underlie memory performance. These findings are analogous to the neurological evidence in the perceptual literature that has demonstrated activation associated with a visual scene to be spread across many different cortical areas.

Second, on occasion individuals will only recall some of the details that were associated with a past event. For instance, people will sometimes say things like “I know that his name started with a *J* but I can not remember what it was”. This is indicative of the tip of the tongue phenomenon (see Brown, 1991 for a review). Even information that is well known to an individual can become temporarily unavailable. In addition to features merely becoming temporarily unavailable, many memory researchers assume that the details associated with a memory become dissociated from one another and that they fade over time (Johnson & Chalfonte, 1994; Johnson, Hashtroudi, & Lindsay, 1993; Reyna & Lloyd, 1997; Tulving, 1983).

In situations where people cannot remember all of the features from a past event, guided memory techniques occasionally are used by therapists and law enforcement officials in an attempt to help the individual *recover* the remaining details of the event (Hyman & Kleinknecht, 1999; Loftus, 1993). When interviewed using these techniques a person is compelled to search their memory, imagine what might have happened or think about what happens in situations like the one they are trying to remember. Such techniques have been demonstrated to foster false memories in lab based experiments (Hyman, Husband, & Billings, 1995; Loftus & Pickrell, 1995; Pezdek & Hodge, 1999). One of the most popular explanations of the results from such experiments is that these techniques encourage individuals to extrapolate details for these events. When forced to extrapolate details, individuals may unknowingly borrow features from other real events to provide flesh to the false memories that they are creating and in doing so, produce memory conjunction errors, a process that has been referred to as *content borrowing* (Lampinen, Meier, Arnal, & Leding, 2005; Lampinen, Ryals, & Smith, 2008).

Additionally, laboratory based procedures have demonstrated memory for features in the absence of configural information using simpler materials. For example, Chalfonte and Johnson (1996) presented their participants with 30 colored drawings of common objects. Each drawing was presented in a cell of a 7 x 7 grid. Each of the objects was positioned in a different location within the grid and was printed in a different color. For example, participants might have viewed a drawing of a blue chair located in the top-left hand corner of the grid. In this design, object, location and color were all considered to be basic features represented within the gestalt of each of the pictures presented in the grid.

In a series of three experiments, young and elderly adults viewed arrays such as these and later completed a recognition memory test. The questions of interest were whether or not their participants would be able to: 1) correctly recognize that a chair was presented in the array, 2) recognize that the color blue was presented in the array and 3) recognize that an object had been positioned in the top left hand corner of the grid. Recognition performance of this sort

provided a measure of the ability of their participants to recognize individual features. In addition, Chalfonte & Johnson were interested in whether or not their participants would be able to correctly recognize objects, colors and location in the appropriate relationship to one another. Recognition of this sort provides a rough estimate of the ability of their participants to bind features together.

Past research has demonstrated normal aging to impair memory (Light, 1991; Spencer & Raz, 1995). Consistent with this past research, elderly participants demonstrated comparatively worse memories for location information than their younger counterparts. However, the elderly participants experienced selective deficits in their memory. Their memories for object and color information was equivalent to that of the younger participants. In our blue chair example, the elderly participants would recognize that the color blue and that a picture of a chair had been presented previously, but they would have difficulty remembering exactly where these details had been located previously. This dissociation suggests that each of these features was stored in separate representations, providing evidence for memorial features.

In addition, the elderly participants showed a deficit in their ability to recognize these simple features in the appropriate relationship to one another. Chalfonte and Johnson (1996) concluded that the deficit of location information hindered the ability of their elderly participants to accurately bind object and color features. Recalling where the color blue and the chair had been located would allow these features to be bound together into a representation of a blue chair. A similar conclusion was drawn by researchers investigating illusory conjunctions. Prinzmetal and his colleagues (Ashby, et al 1996; Prinzmetal, et al 2002) theorized that location allows for perceptual features to be bound together. Reduced access to location information results in an inability to adequately bind features together. This same logic applies to the research of Chalfonte and Johnson. Location information informs a memorial feature binding process allowing for memorial features to be bound together. This explanation is very compelling given the perceptual nature of the materials used by Chalfonte and Johnson (1996).

If we assume that memories are composed of discretely processed features, how then are they bound together? Given the results presented thus far, location appears to be one type of structural information that informs a memorial feature binding process. Yet, presumably there are several different types of structural information that function to hold features in relationship to one another. These various types of information would comprise what has been referred to as a configural memory trace (Reinitz, et al., 1994; Reinitz & Hannigan, 2001). Similar to Johnson and her colleagues, we stress that feature binding is a process that is informed by many forms of structural representations. The context in which a type of structural information is presented will determine how diagnostic it will be to the binding process.

This line of thinking gives rise to an important question. Does the structure of an event generate an independent memory trace? In *Essays in Radical Empiricism*, William James (1912) suggested that the structure inherent in an object was just as real as the features themselves. This concept is similar to that proposed by several existing models of memory. For example, a schema is in essence a type of configural trace. A script for going to a restaurant allows a person to understand how the various features that make up the visit should relate to one another (Bower, Black & Turner, 1979). Of course, a schema represents a general level of knowledge, instead of an event specific level of knowledge (Forbus, Gentner,

& Law, 1994). If an event level representation was not available individuals could rely upon schemas to piece together an event specific memory. However, some theories do posit configural representations to exist at an event level. For instance, Forbus et al. appealed to an event specific level of configural information in their account of analogical reminding. Similarly, Brainerd and Reyna (2002) propose that each event gives rise to a gist representation and that this gist representation informs a reconstructive free recall process (Brainerd, Wright, Reyna, & Payne, 2002).

As such, researchers posit that both feature and configural representations are encoded for memorial events. Presumably, assessing these configural traces would allow a person to accurately piece back together the features that were originally experienced. Notice that we have outlined several different types of configural representations that could be encoded. Location, the gist, and even the theme of an event provide a blueprint for how the individual features of an event relate to one another. Potentially, some of these traces have more longevity in memory than others. For instance, location is a surface feature that should decay from memory more rapidly than the gist or theme of an event (Reyna & Lloyd, 1997). Such differences might undermine the ability of a person to accurately piece together the past. Regardless, there seems to be reason to believe that features make up our memories for the past. However, there is mounting evidence that these features engender a sense of familiarity in the absence of the ability to consciously recollect them, and that this familiarity biases responding on recognition memory tests in the memory conjunction paradigm.

The Role of Familiarity

Thus far we have argued that an errant feature binding process is responsible for both illusory conjunctions and memory conjunction errors. However, that conclusion should be drawn with caution because processes other than feature binding underlie false alarms in the memory conjunction paradigm. This is important because memory conjunction errors are the result of features from different events being erroneously combined to form a false memory. These alternative processes need to be identified and accounted for in an attempt to ascertain the extent to which inappropriate feature binding results in memory errors in this paradigm.

Consider, for instance, Jacoby's (1991) dual process account of recognition memory. According to Jacoby, recognition memory results from two processes, recollection and familiarity. Conscious recollection is a relatively slow, deliberate process that accurately retrieves contextual and relational information. Notice that recollection implies the retrieval of a bound memory trace, without providing a clear explanation of how this binding would occur. Familiarity, on the other hand, is a fast, automatic process that relies on feature matches, in the absence of contextual or relational information. This process is often thought of in terms of global feature matching, such as in MINERVA2 (Hintzman, 1988).

Familiarity is experienced as an ease of processing, which can occur because the information itself or something related to it was presented previously. For instance, the presentation of *cup* at study results in perceptual fluency for the presentation of the word *cut* at a later time, and this perceptual fluency is experienced as familiarity for that item. In the absence of any information to the contrary (e.g., remembering that *cup* was presented opposed to *cut*), participants likely will misattribute this sense of familiarity for the test item to the study session, resulting in the false acceptance of *cut*. In support of this idea, Jacoby

and Dallas (1981) found a correspondence between performance on a perceptual recognition task and an old new recognition memory test. Words that were more easily recognized on a perceptual recognition task were more likely to be recognized as old on an old new recognition memory test.

In addition, the presentation of *cup* at study would result in a sense of semantic fluency for the later presentation of the word *mug*. Semantic fluency for an item can also be misattributed to a previous study session resulting in the false acceptance of items that were not presented at study. For instance, Brainerd, Reyna and Mojardin (1999; see also Odegard & Lampinen, 2005) found that presenting participants with a test item's synonym or antonym at study increased rates of false alarms to the test item. The conclusion drawn from results such as these is that both perceptual and semantic familiarity should influence the acceptance of targets, conjunction lures and feature lures on a recognition memory test (Watson, Balota, & Sergent-Marshall, 2001).

Presumably, target acceptance occurs either because the test item is consciously recollected or because it seems familiar to the participant. According to the dual process model, the false recognition of conjunction and feature lures results from familiarity. People will falsely accept conjunction lures because they previously saw all of their perceptual features. The fact that all of the features were presented previously evokes an ease of processing, which results in a sense of familiarity with the conjunction lure. This sense of familiarity can result in the false acceptance of a conjunction lure. However, only half of the perceptual features of a feature lure were presented previously. Consequently, feature lures should seem less familiar to a participant than conjunction lures. Of course, none of the perceptual features that make up foils were studied previously, and the study session should not influence levels of familiarity experienced for these items. The amount of overlap shared between the different recognition items with the items presented at test roughly corresponds to the rates at which these test items are falsely accepted. Thus, familiarity provides an alternative account of memory conjunction errors, one that does not rely on an errant feature binding process.

In support of the role of familiarity in the memory conjunction error paradigm, manipulations known to influence recollection often fail to influence the acceptance of conjunction lures (Jones & Jacoby, 2001; Jones, Jacoby, & Gellis, 2001), while these same manipulations decrease the rate at which participants accept targets. For instance, past research has demonstrated that dividing attention at study and test decreases participants' abilities to utilize recollection but not familiarity (Gruppuso, Lindsay, & Kelley, 1997; Jacoby, 1996). Dividing attention at encoding and retrieval did not decrease rates of false alarms to conjunction and feature lures but did decrease the number of hits for targets (Jones & Jacoby, 2001). These results suggest that participants rely on recollection when accepting targets, but not when falsely accepting conjunction and feature lures.

In addition, Jones and Jacoby (2001) and Jones, et al. (2001) manipulated response time to investigate the influence of recollection and familiarity in the memory conjunction paradigm. Recall that familiarity is defined as a fast, automatic process. Even under conditions of speeded response, participants should still have access to familiarity. Conversely, recollection is a slower, more deliberate process (see Yonelinas, 2002 for a review). Speeding the rate at which participants provide recognition responses should preclude the ability of the participants to use recollection. When forced to provide speeded

recognition responses, participants correctly accepted fewer targets but accepted just as many conjunction and feature lures.

These results underscore the importance of familiarity in the acceptance of conjunction and feature lures. One might conclude that false alarms to conjunction lures merely result from familiarity. As such, these results do not provide compelling evidence that erroneous feature binding inappropriately combines features from multiple memories together to form memory conjunction errors.

Evidence for Feature Binding in Memory

While familiarity most certainly plays a role in the acceptance of both conjunction lures and feature lures in this paradigm, it should be noted that evidence exists suggesting that something more than familiarity underlies false alarms to conjunction lures. First, familiarity alone cannot account for an illusory sense of recollecting conjunction lures when they are presented at test. Yet, participants have reported an illusory sense of recollection to accompany false alarms to conjunction lures of compound words, line drawn faces and autobiographical memories (Reinitz & Hannigan, 2004; Reinitz, et al., 1994; Odegard & Lampinen, 2004). Reinitz et al. (1994) had their participants view 8 black and white images of line drawn faces and later complete a recognition memory test. Conjunction lures were formed by taking the eyes and nose from one presented face and combining them with the hair and nose from another presented face. After falsely accepting some conjunction lures, participants categorized their memorial experiences for conjunction lures in the remember sense. Remember judgments are to be made when a participant can recollect some aspect of a recognition item's previous presentation (Rajaram, 1993). So these participants reported being able to remember these features having been presented together.

Additionally, we obtained evidence for illusory or phantom recollection in a study of memory conjunction errors for autobiographical events (Odegard & Lampinen, 2004). Participants in our second study reported life events in a diary. We constructed conjunction lures by taking features from one event and supplanting them into another event. For example, the person from one event might be placed into another event. Participants not only falsely recognized some of these conjunction lures, but they also reported being able to actually *remember* the features as having been present during the wrong event. In addition, we obtained similar results using compound words. By collecting confidence data along with old new recognition performance we observed that participants were extremely confident that a subset of falsely accepted conjunction lures had actually been presented (Lampinen, Odegard, & Neuschatz, 2004). By plotting ROC curves of these data we obtained additional evidence for phantom recollection of conjunction lures.

Second, familiarity for conjunction lures should be influenced solely by the previous presentation of the constituent features of the conjunction lures. However, other factors influence false alarms to conjunction lures. For instance, conjunction lures composed of features that were presented close together in time are more likely to be falsely recognized than conjunction lures composed of features that were presented further apart in time (Kroll et al., 1996; Hannigan & Reinitz, 2000; Reinitz, & Hannigan, 2004). Perceptual fluency should not be influenced by the temporal proximity of one feature to another. Also, participants are more likely to falsely accept a conjunction lure comprised of features that were taken from

events that both belong to the same type or category of events (Hannigan & Reinitz, 2003; Odegard & Lampinen, 2004). For example, we observed people to experience more illusory memories when we constructed conjunction lures using details from two events that were categorized by the participant as being the same type of event (e.g., social event).

Recall that one of the general conclusions drawn from reviewing the literature on perceptual illusions was that features were more likely to migrate within a perceptual unit than between a perceptual unit. Likewise, Hannigan and Reinitz (2003) found increased rates of false alarms for conjunction lures composed of features taken from faces that were presented together simultaneously. They have also observed the same to be true of conjunction lures for compound words (Reinitz & Hannigan, 2004). Those objects that are presented simultaneously are more likely to be processed as a perceptual unit than items that are separated across time.

Even when events are separated across time, category membership groups events together into memorial units. Being grouped in such a fashion increases the likelihood that features between them will be inappropriately bound together forming a memory conjunction error. Again, we observed features from life events that were classified as belonging to the same category of events to form conjunction lures that were more likely to be falsely accepted than by combining features from two life events that were classified as belonging to different categories.

Recall that Prinzmetal (1981) observed similarity to underlie the formation of illusory conjunctions. Presumably this is also true of memorial binding. Increased similarity between events helps to group these events together in memory. When configural information is lost other information must be utilized. In some cases, features from events that belong to similar events may start to commingle forming memory conjunction errors.

Finally, although familiarity can account for the false recognition of conjunction lures, it fails to provide an explanation for free recall of conjunction errors. Again, past research has demonstrated that conjunction errors are reported on free recall memory tests (Odegard & Lampinen, 2004; Reinitz & Hannigan, 2004; Reinitz, et al., 1994). Reinitz et al. (1994) observed their participants to falsely recall recombinations of sentences that were presented at study. Reinitz and Hannigan (2004) observed their participants to recombine words from compound words presented at study to form conjunctions. Also, our participants falsely recalled life events that contained combinations of features from different events. Although free recall of conjunction errors was small in each of these cases, these results strongly suggest that something other than mere familiarity underlies memory performance in the memory conjunction paradigm. Yet, it should be stressed that familiarity most certainly contributes to performance in this paradigm.

Collectively, the results reviewed from the memory conjunction literature suggest that familiarity and errant feature binding both contribute to false alarms to conjunction lures. Earlier we identified several criteria that if followed help to ensure that perceptual errors were indeed illusory conjunctions, resulting from the errant binding of presented features. Likewise, there are criteria that if followed help to ensure that researchers are investigating errors resulting from the errant binding of memorial features. These criteria are born out of the processes assumed to underlie memory conjunction errors.

First, to conclude that false memories are the product of errant feature binding, we must determine that people are not guessing. Second, one must control for the extent to which false memories result from familiarity in the absence of any errant feature binding. Of course, an

initial feeling of familiarity may compel a person to engage in a reconstructive process, resulting in the errant binding of features (Lampinen, Meier et al., 2005; Lampinen et al., 2008; Lampinen, Faries, Neuschatz, & Toggia, 2000; Lampinen, Neuschatz, & Payne, 1999). However, given that recognition responses can be based solely on familiarity, such errors should not be considered memory conjunction errors. Third, feature traces should be derived from actual events. For instance, they should not be extrapolations from prototypes or schemas. Although, participants may strategically use schematic knowledge when filling in the details, these details need to correspond to actual features from a person's past. Finally, these memorial features must be *free floating*, allowing them to be inaccurately bound together. Just as Treisman and Gelade (1980) referred to unbound features as "free floating" features, Tulving (1983) referred to memorial details detached from a knowledge structure as "free radicals." Just as free floating features can be inappropriately bound together to produce illusory conjunctions, free radicals can be inappropriately bound together to produce illusory false memories.

Measuring Memory Conjunction Errors

Criteria 1 and 2 stress that multiple latent memory processes and guessing underlie the behavioral data collected in the memory conjunction paradigm. Consequently, researchers are unable to rely strictly on false alarms to conjunction lures as a means of measuring memory conjunction errors. Thus, we must find a means of achieving the first two criteria. A similar obstacle was present in the illusory conjunction literature. Researchers interested in illusory conjunctions had to control for the extent to which participants responded based on faulty memories and strategic guessing, opposed to faulty perception of what was presented. To control for these other processes, a comparison was made between the rates of falsely accepting conjunction and feature lures. The extent to which participants were more likely to falsely accept conjunction lures than feature lures was seen as evidence of binding errors.

This logic was mathematically conceptualized by Prinzmetal and Millis-Wright (1984) in equation 1. The application of the logic inherent in equation 1 to memory conjunction errors results in the formation of equation 2.

$$P_{conj} = \left[\frac{Con_{error} - Feature_{error}}{1 - Con_{error}} \right] \quad \text{Equation 2}$$

In this equation, rates of guessing are assumed to be equivalent for conjunction and feature lures. Thus, subtracting feature errors from conjunction errors corrects for guessing.

Unfortunately equation 2 will not provide a pure estimate of illusory conjunctions, because of differences between the illusory conjunction and memory conjunction paradigms. For one, familiarity can result in false alarms to both targets and conjunction lures. In addition, participants can accept both conjunction and feature lures because they recall a previously presented feature making up the item and assume the other feature to have been presented as well. This has been referred to as partial recollection (Marsh, Hicks, & Davis 2002; Jones & Jacoby, 2001). It could be assumed that subtracting out the acceptance of feature lures from the acceptance of conjunction lures would correct for both partial

recollection and familiarity. Of course, this is true only if conjunction and feature lures are equivalent in the rate at which they evoke familiarity and partial recollection.

Yet, these assumptions are not true. Conjunction lures are more familiar than feature lures. Also, it is not self evident that partial recollection is equivalent for conjunction and feature lures. Both of the features in a conjunction lure were studied previously, changing the probability that an individual will recollect the prior presentation of one of these features in comparison to feature lures. Thus, a simple subtractive correction will not adequately control for familiarity and partial recollection. Instead, methods to measure the influence of recollection, memory conjunction errors, partial recollection and familiarity on the acceptance and rejection of targets, conjunction lures and feature lures need to be introduced. Therefore, we introduce several means by which these processes could be measured, but first, we briefly define the processes that are of interest in this paradigm.

It is now widely held that recollection can play two roles (Brainerd & Reyna, 2002; Brainerd, Wright, Reyna, & Mojardin, 2001; Lampinen, et al., 2004; Odegard, Koen, & Gama, 2008; Odegard, Lampinen, & Toglia, 2005; Rotello & Heit, 1999; 2000; Rotello, Macmillan, & Van-Tassel, 2000, Yonelinas, 1997). Recollection can lead to the acceptance of targets and the rejection of related lures. In the current paradigm, these responses are fostered by the ability of an individual to access relational information for the constituent features of a memorial event. Recollection of relational information should result in the acceptance of a target and the rejection of both conjunction and feature lures. For example, if when presented with *blackbird* at test a person is capable of recollecting that *black* was presented with *mail* at study, this information should allow a person to appropriately reject *blackbird*. Of course, a person could imagine situations in which this strategy would be more useful than others. For example, in previous research (Lampinen et al., 2004), we have told participants that studied items did not share the same features. When given these instructions, recollecting a target is maximally likely to result in the rejection of conjunction or feature lures. However, one could also imagine a situation in which features were shared among the different study items. In this situation, recollecting the presentation of a target will be less diagnostic when presented with a feature or conjunction lure. Regardless, utilizing recollection to reject lures in this manner has been referred to as recollection rejection and should occur for both conjunction and features lures and this has indeed been observed to be the case (Lampinen et al. 2004; Odegard, et al., 2008; Odegard, et al., 2005).

When relational information is unavailable but the features making up the recognition item are recollected, a person may commit a memory conjunction error. Memory conjunction errors can result in the acceptance of targets and conjunction lures and should be experienced as compellingly real memories. In addition, partial recollection can occur. Participants may recollect one of the features presented in a recognition test item and assume that the other had been presented as well based on familiarity. Targets, conjunction lures, and feature lures, all of which are composed of at least one feature that was presented at study, could be accepted based on partial recollection. Finally, participants may accept targets, conjunction lures, and features lures based on familiarity. A list and description of these processes is provided in Table 1.

When addressing the problem of measuring each of these memorial processes, differences between recollection and familiarity can be exploited to dissociate the processes from one another. Yonelinas (2001) discussed the three C's of recollection: consciousness, control, and confidence. Recollection is accompanied by a conscious level of awareness for

the context or some detail associated with the presentation of an item, but familiarity is experienced as a general feeling of previously having experienced the material. Also, recollection allows a person to exert control over the testing environment. For example, recollection allows a person to selectively respond to information presented from different sources, but familiarity does not afford a person with this level of control. Finally, recollection is typically associated with high levels of confidence, but familiarity judgments are made under different levels of confidence corresponding to how familiar the test item is to the participant. Each of these differences can be utilized to distinguish between recollection, memory conjunction errors, partial recollection and familiarity.

To begin, self report techniques have been used to access the level of awareness that accompanies participants' memories for the past (Gardiner & Java, 1993; Odegard & Lampinen, 2005; Odegard et al., 2005). For example, both remember know judgments and the memory characteristic questionnaire have been used to address the phenomenology that accompanies hits and false alarms to recognition test items (see Lampinen et al., 1998 for a review of these methodologies). Given that recollection processes (i.e., Recollection, Recollection Rejection, Partial Recollection) are experienced at a conscious, reportable level, a straightforward means of investigating these processes is to require participants to complete a modified recognition test that includes remember know judgments. The inclusion of remember know judgments provides participants with the opportunity to self report the quality of their memory experience.

Table 1. Parameters in the Conjunction Memory Model

Recollection (R)	The ability to consciously recollect the previous presentation of an event in its entirety
Recollection Rejection of Conjunction Lures ($R_{\text{conjunction}}$)	The ability to reject a conjunction lure by consciously recollecting the context in which at least one of the old features in the lure had been presented previously.
Recollection Rejection of Feature Lures (R_{feature})	The ability to reject a feature lure by consciously recollecting the context in which the old feature in the lure had been presented previously.
Memory Conjunction Error (MC)	The recollection of both of the constituent features of a conjunction that are inappropriately bound together resulting in an illusory sense of recollecting of the conjunction lure.
Partial Recollection of Targets (PAR_{target})	Recollecting one of the features of a target and assuming based on familiarity that the item as a whole was presented at study.
Partial Recollection of Conjunction Lures ($PAR_{\text{conjunction}}$)	Recollecting one of the features of a conjunction lure and assuming based on familiarity that the item as a whole was presented at study.
Partial Recollection of Feature Lures (PAR_{feature})	Recollecting one of the features of a feature lure and assuming based on familiarity that the item as a whole was presented at study.
Familiarity of Targets (F_{target})	Accepting a target because the features seem familiar.
Familiarity of Conjunction Lures ($F_{\text{conjunction}}$)	Accepting a conjunction lure because the features seem familiar.
Familiarity of Feature Lures (F_{feature})	Accepting a feature lure because the features seem familiar.

Remember know judgments have been used with the memory conjunction paradigm in past research (Odegard & Lampinen, 2004; Odegard et al., 2005; Reinitz & Hannigan, 2004; Reinitz, et al., 1994), but these self report judgments were not used to systematically distinguish between those items that were recollected from those items that were only partially recollected. To accomplish this, the testing procedure would be modified to allow participants to provide old new and remember know judgments for each of the features making up a recognition item and for the item as a whole. For instance, a person presented with the recognition item *blackbird* would make an old new judgment for the word *black*. If the participant judged the feature to be old, a remember know judgment would be made for the word *black*. The participant would do the same thing for *bird*. These judgments provide an estimate of a participant's ability to remember previously presented features and the extent to which these features are recollected (i.e., remember judgment) or simply seem familiar (i.e., know judgment) to the participant.

Next, for those items where both features were judged to be old, the participant would determine if the features had been presented together at study. In our current example, a participant would determine if *black* and *bird* had been presented together. After making this judgment, a remember know judgment would be made. The remember know judgment provides a means of determining whether or not the participant has the feeling of consciously recollecting the features together, or whether the participant simply knows that the features were presented together. Additionally, this provides the opportunity for the participant to report the ability to consciously recollect one or both of the features as having been presented in a different context. In such instances, a new judgment would be made for the item as a whole (i.e., *black* and *bird* were not presented together) and then a remember judgment would be made as well. Rejecting items in this fashion is indicative of recollection rejection.

This technique provides a means of accessing the extent to which participants falsely accept conjunction lures as old after first having identified the individual features as being old. It also provides a means of estimating the extent to which participants' report consciously remembering some aspect about the feature (i.e., remember judgment) opposed to simply finding the feature to be familiar (i.e., know judgment). In addition, it provides a means of measuring the extent to which participants are able to consciously recollect the features as having been presented together. As such, the conscious level of experience that accompanies recollection of features and configural information can be used to provide gross estimates of the memory processes outlined in Table 1. For instance, partial recollection would be reported as remembering one feature and finding the other to be familiar, when the item as a whole is accepted as old.

Yet, self report techniques are subjective in nature and are difficult to correct for guessing. Furthermore, Lampinen et al. (1998) raised three major concerns with remember know judgments. For one, great care needs to be taken to ensure that participants fully understand that a remember judgment should only be made when they are capable of consciously recollecting some aspect of the recognition item. Secondly, they noted standardized instructions have not been introduced for this procedure. Some remember know instructions sets may handle the first concern better than others. Finally, the procedure forces participants to categorize their judgments into one of two types of memories. This categorization is based on an assumption that memory is composed of two types of memory, recollection and familiarity. Although our modification to the remember know procedure

allows us to provide estimates of several different types of memories, these memories are derivations of recollection and familiarity.

To address some of these concerns, the aspect of control inherent to recollection has been used to dissociate the influence of latent memory processes on recognition performance. For instance, past researchers utilized control inherent to recollection to provide estimates of familiarity and recollection using the process dissociation technique (Jacoby, 1991; 1996). In this technique, the ability to distinguish between information presented from two different sources (e.g., list 1 and list 2) is used to dissociate the influence of conscious recollection from familiarity on recognition responses. To estimate these effects, two sets of recognition instructions, inclusion and exclusion, are used. Exclusion instructions require participants to distinguish the source from which information was presented at study and to accept only those items that were presented from one of the two sources (e.g., list 2). Inclusion instructions allow participants to select items from either of the two sources.

Thus, in our example, the proportion of list 1 items chosen under the inclusion instructions minus the proportion of list 1 items chosen under the exclusion instructions provides an estimate of the recollection process. The logic is that list 1 items selected under the exclusion instructions resulted from familiarity and guessing, but the acceptance of list 1 items under the inclusion instructions resulted from recollection, familiarity and guessing.

$$R = I - E$$

Equation 3

Familiarity can be estimated as the probability of selecting an item under the exclusion instructions divided by the probability of not recollecting the item, when recollection and familiarity are assumed to be independent.

$$F = E / (1 - R)$$

Equation 4

This model assumes that recollection can be used to oppose familiarity. A person capable of recollecting the source of a test item can utilize this information to respond appropriately under exclusion instruction. This logic can be modified and applied to the memory conjunction paradigm. In the Process Dissociation procedure participants are asked to make source judgments about previously presented information (i.e., within which list was a word presented). Similarly, participants tested in the memory conjunction paradigm are asked to distinguish between recognition test items that contain features presented in the same relationship to one another at test as they were at study (i.e., targets) and those recognition test items that are previously unstudied combinations of these previously studied features (i.e., conjunction lures). The only difference between a target and a conjunction lure is the relationship that the individual features share among one another.

When modifying the process dissociation procedure for use with the memory conjunction paradigm, two sets of instructions analogous to exclusion instructions would be introduced. One set of exclusion instructions would instruct participants to accept only targets (T instructions). The second set would instruct participants to accept only conjunction lures (C instructions). Recollecting the appropriate configural information needed to bind features together will allow participants to appropriately respond to targets and conjunction lures under these two instruction sets, realizing of course that feature lures should be rejected under both of these instruction sets. Inclusion instructions can be modified to request that

participants accept recognition test items that are composed of at least one feature that was presented at study. Thus, participants are asked to accept targets, conjunction lures and features lures (T+C+F instructions).

These instruction sets allow memory processes thought to underlie recognition memory performance in the memory conjunction paradigm to be measured. As was the case with process dissociation, equations can be derived for estimating the extent to which participants' responses are based on different memory processes. For instance, estimates of recollection of targets can be derived from equation 5.

$$R_{(\text{Targets})} = \text{TAR}_{(\text{acceptance, T instructions})} - \text{TAR}_{(\text{acceptance, C instructions})} \quad \text{Equation 5}$$

The estimate derived from Equation 5 is based on the ability of participants to use conscious recollection to control their responding under the different instructions. Furthermore, we would argue that configural information enables participants to accurately recollect the past. For instance, participants should only accept targets under T instructions when they recognize that the features composing the features previously were presented in that configuration. Additionally, access to this same configural information should enable participants to reject targets under the C instructions. More formally, targets accepted under the T instructions are based on recollection, memory conjunction errors, partial recollection and familiarity.

$$\begin{aligned} \text{Targets acceptance (T instructions)} &= R + (1-R) MC + (1-R) (1-MC) PAR \\ &\quad + (1-R) (1-MC) (1-PAR) F \\ &\quad + (1-R) (1-MC) (1 - PAR) (1- F) B \end{aligned} \quad \text{Equation 6}$$

Targets accepted under C instructions are accepted based on partial recollection, familiarity and response bias.

$$\begin{aligned} \text{Targets acceptance (C instructions)} &= (1-R) (1 - MC) PAR + (1-R) (1- MC) (1 - PAR) F \\ &\quad + (1-R) (1-MC) (1 - PAR) (1- F) B \end{aligned} \quad \text{Equation 7}$$

As such, equation 5 provides an estimate of participants' abilities to recollect the previous presentation of a target by subtracting out the influence of everything except recollection and memory conjunction errors on the acceptance of targets under T instructions. If memory conjunction errors really do occur, there is no way of dissociating these errors from the recollection of targets. However, this very same problem of dissociating recollection and illusory recollection memory for targets from one another presents itself to many other techniques as well (Brainerd, et al., 1999; Brainerd, et al., 2001; Jacoby, 1991; 1996; Yonelinas, 1997).

Likewise, access to the appropriate configural information for a set of features should allow participants to correctly respond to conjunction lures under the different instructions sets. For example, under T instructions participants should reject conjunction lures. The occurrence of recollection rejection should in large part be due to the availability of configural information, providing participants with the control needed to correctly reject conjunction lures under the T instructions and to accept them under the C instructions.

Equation 8 provides an estimate of the ability of participants to engage in recollection rejection when responding to conjunction lures.

$$Rr_{(\text{conjunction lure})} = \text{Con}_{(\text{acceptance, T+C+F instructions})} - \text{Con}_{(\text{acceptance, T instructions})} \quad \text{Equation 8}$$

Conjunction lures should be accepted based on all the processes outline in table 1 under T+C+F instructions.

$$\begin{aligned} \text{Conjunction lures acceptance} &= Rr + (1 - Rr) MC + (1 - Rr) (1 - MC) PAR \\ (\text{T+C+F instructions}) &+ (1 - Rr) (1 - MC) (1 - PAR) F \\ &+ (1 - Rr) (1 - MC) (1 - PAR) (1 - F) B \end{aligned} \quad \text{Equation 9}$$

However, the ability to recall the appropriate configural information should result in conjunction lures being rejected under T instructions.

$$\begin{aligned} \text{Conjunction lures acceptance} &= (1-Rr) MC + (1 - Rr) (1 - MC) PAR \\ (\text{T instructions}) &+ (1 - Rr) (1 - MC) (1 - PAR) F \\ &+ (1 - Rr) (1 - MC) (1 - PAR) (1 - F) B \end{aligned} \quad \text{Equation 10}$$

Again, subtracting these probability statements (i.e., Equations 9 and 10) from one another reduces the statements to recollection rejection.

Finally, equation 11 provides an estimate of memory conjunction errors for conjunction lures.

$$MC_{(\text{conjunction})} = (\text{Con}_{(\text{acceptance, T instructions})} - \text{Con}_{(\text{acceptance, C instructions})}) / (1 - Rr_{(\text{conjunction})}) \quad \text{Equation 11}$$

Conjunction lures are accepted based on memory conjunction errors, partial recollection, familiarity and response bias under T instructions.¹

$$\begin{aligned} \text{Conjunction lures acceptance} &= (1-Rr) MC + (1 - Rr) (1 - MC) PAR \\ (\text{T instructions}) &+ (1 - Rr) (1 - MC) (1 - PAR) F \\ &+ (1 - Rr) (1 - MC) (1 - PAR) (1 - F) B \end{aligned} \quad \text{Equation 12}$$

Conjunction lures are accepted based on partial recollection, familiarity and response bias under the C instructions.

$$\begin{aligned} \text{Conjunction lures acceptance} &= Rr + (1-Rr) (1 - MC) PAR \\ (\text{C instructions}) &+ (1 - Rr) (1 - MC) (1 - PAR) F \\ &+ (1 - Rr) (1 - MC) (1 - PAR) (1 - F) B \end{aligned} \quad \text{Equation 13}$$

Subtracting the acceptance of conjunction lures under C instructions from the acceptance of conjunction lures under target+conjunction+feature instructions (i.e., Equation 9) removes all memory processes except memory conjunction errors.

¹ Notice that an assumption is being made in equation 11 as to the precedence of recollection rejection over memory conjunction errors. A similar assumption is made by several other models, such as Conjoint Recognition (Brainerd, et al., 1999) and Phantom Recollection (Brainerd, et al., 2001).

Although this technique would provide parameter estimates for some memory processes, it fails to provide a measure of partial recollection. At best, this approach would yield an estimate of the additive influence of familiarity and partial recollection on recognition responding. In addition, this approach provides no means of formally modeling the memory processes of interest, because the outcome space provides only 12 degrees of freedom². As is evident from Table 1, the number of memory processes of interest approaches the degrees of freedom allotted in the outcome space. With the inclusion of independent estimates of response bias for the three instruction conditions, any formal model becomes supersaturated. This would preclude reliable parameter estimates from being obtained. In addition, it precludes us from testing the fit of the model.

To account for the problem of measuring response bias, confidence judgments have been used to provide estimates for several of the memory processes of interest in the memory conjunction paradigm. For example, Yonelinas (1997; 1999) devised a method using ROC analysis to provide estimates of recollection and familiarity. Subsequently, we developed a similar model that provides estimates of recollection, illusory memories for lures, recollection rejection and familiarity (Lampinen, Odegard, Blackshear, & Toglia, 2005).

Traditionally, researchers have participants make old new recognition judgments guided by standard recognition instructions, while providing confidence judgments in their old new judgments. Plotting rejection and acceptance rates at each confidence level generates an ROC curve. In a standard ROC curve, targets are plotted on the Y axis and unrelated lures are plotted on the X-axis. By the standard signal detection account, ROC curves should begin in the bottom left hand corner (0,0) of the graph and curve up into the top right hand corner of the graph (1,1).

Yonelinas (1997; 1999) observed that even when participants were being so conservative that they should not accept any test items, they were still accepting some targets. This caused the ROC curve to intersect the Y axis above (0,0). He suggested that this provided evidence for a second memory process, recollection, in addition to the process of familiarity. This high level of confidence presumably resulted from the ability of the participant to consciously recollect the target. Graphically, the distance between 0 and the intercept of the Y axis represents recollection of targets.

We adapted this logic for application with the two recollection processes thought to underlie recognition performance for related lures, phantom recollection and recollection rejection. First, participants sometimes report that their memories for related lures have been extremely compelling. These illusory memories are experienced as recollections. Brainerd et al. (2001) have referred to them as phantom recollections. As such, we refer to our ROC model as Phantom ROC (PROC). We plotted ROC curves in which related lures were placed on the Y-axis and unrelated lures were placed on the X-axis. Similar to Yonelinas (1997; 1999), we observed the Y-intercept of this ROC curve to be non zero. Even when participants were being maximally conservative, they experienced phantom recollections for some of the related lures. Graphically, the distance between 0 and the intercept of the Y-axis represents phantom recollection of related lures. We have modeled performance in the memory conjunction paradigm using this approach and observed participants to experience phantom recollection for conjunction lures, but the same was not true for feature lures.

² Actually, two of the probability statements for feature lures are redundant, reducing the number of degrees of freedom to 11.

Furthermore, we observed the curve to fall below (1,1). Even when participants were willing to accept every single unrelated distractor based on familiarity, there were some related items that they were unwilling to accept. Presumably, participants' ability to engage in recollection rejection would allow them to reject even the most familiar of related lures. Graphically, the distance below (1,1) and the point at which the curve intersects on the right hand side of the graph represents recollection rejection of related lures. Again we have plotted data from the memory conjunction paradigm using this approach and observed robust estimates of recollection rejection for both conjunction and feature lures. Finally, familiarity for targets and related lures is estimated using d' (Snodgrass & Corwin, 1988).

Although, we have modeled data from the memory conjunction paradigm and obtained estimates of recollection, phantom recollection, recollection rejection and familiarity, PROC also fails to provide an estimate of partial recollection. Fortunately, PROC can be adapted to provide estimates for all of the processes of interest in the memory conjunction paradigm with the introduction of the multiple instruction sets discussed earlier. By obtaining confidence judgments for participants' responses under both inclusion and exclusion instructions a measure of all the processes outlined in Table 1 can be obtained.

Under inclusion instructions (i.e., accept target, conjunction, and feature lures) participants should accept feature lures. When instructed in this fashion, participants will be capable of relying on their ability to recollect the one old feature in a feature lure in order to accept feature lures under extremely high confidence. As was the case with targets and conjunction lures under standard instructions, the extent to which participants recollect the one old feature in a feature lure will elevate the intercept of the ROC curve at the Y-axis above zero. This should graphically represent the ability of participants to recollect that one of the features in the item was old. Thus, this combination of the control and confidence inherent to recollection based processes provides an eloquent way of obtaining estimates for all of the recognition based processes while controlling for familiarity and response bias.

INTERSECT BETWEEN ILLUSORY CONJUNCTIONS AND MEMORY CONJUNCTIONS ERRORS

Given that we can distinguish between the different processes influencing recognition performance in the memory conjunction paradigm, it is important to use these methodologies to better understand these memory processes. In particular, we are interested in understanding how feature memory and binding interact. To provide a basic framework for achieving this goal, we reviewed the literature on illusory conjunctions and memory conjunction errors. Illusory conjunctions and memory conjunction errors are similar to one another in many respects, and many of the factors that have been demonstrated to influence illusory conjunctions have subsequently been demonstrated to influence the formation of memory conjunction errors.

One point to take away from the comparison of illusory conjunctions to memory conjunction errors made here is the need for the systematic exploitation of these similarities to fully explore memory conjunction errors and memory as a whole. Specifically, we suggested that memorial features must be *free floating*, allowing them to be inaccurately bound together to form memory conjunction errors. Although this was one of the basic principles driving the

methodology used to better understand illusory conjunctions, as of yet, researchers investigating memory conjunction errors have failed to follow suit. Recall that perceptual researchers used attention to limit the ability of their participants to form bound object representation effectively increasing the rates of illusory conjunctions. Dividing attention at study could also be used in the memory conjunction paradigm to achieve a similar effect.

Given past research, another variable that should influence the cohesion of a memory trace is the amount of a delay placed between study and test. Researchers suggest that the passage of time causes traces to break apart. Concordantly, the passage of time is also thought to result in the decay of features as well. Thus, it is uncertain how long free radicals are available in memory. Subsequently, we predict the passage of time to influence estimates of recollection rejection, partial recollection and memory conjunction errors more so than familiarity. However, this effect should only be observed to the extent that the passage of time breaks apart traces and the majority of the resultant free radicals do not decay from memory.

Thus, by introducing variables such as divided attention and delay we can break apart memory traces to provide the basic features needed for the formation of memory conjunction errors. This allows us to determine if participants actually commit increased levels of memory conjunction errors, under conditions that should likely produce them. We can also increase the probability that certain types of conjunction errors will be committed, further supporting the basic assumptions about memory conjunction errors previously outlined. Again drawing from insights gained from reviewing the perceptual literature, it becomes clear that grouping principles should constrain the formation of memory conjunction errors. For example, temporal proximity has garnered some attention, and presenting features temporally closer to one another increases the occurrence of memory conjunction errors. Yet, spatial proximity has yet to be investigated in this paradigm, and presumably should have similar results as grouping features together based on temporal proximity. Another variable that should act to group memorial features is the amount of semantic overlap shared between the features composing a conjunction lure and the target items from which the features making up the conjunction lures were sampled.

Semantic similarity is important to the current discussion, because it gets at the heart of the notion of what underlies recollection. Jones and Jacoby (2001) hypothesized that increasing the semantic overlap between targets and conjunction lures would decrease false alarms to memory conjunction errors. This is based on an assumption that the availability of conceptual or semantic information for an item increases the odds that it will be consciously recollected at a later time (Jacoby & Dallas, 1981). This was the case in a set of experiments investigating the influence of meaning on the generation effect for compound words (Gardiner & Hampton, 1985). Likewise, Payne, Neely, & Burns (1986) found meaning to influence retrieval more so than other relationships such as rhyming and phonology. Given these results, surface features do not seem to underlie the ability of participants to retrieve and recollect information from memory.

This makes sense from the perspective outlined by Mandler (1980), who assumed inter-item associates to be formed based on semantic overlap. These inter-item associations increase the ability of an individual to retrieve information from memory. This would suggest that cued retrieval is better served by a semantically opposed to perceptually related cue. For example, being presented with *mug* at test should be more likely to cue the retrieval of the prior presentation of *cup* than the presentation of *cut*. As such, one would expect recollection

rejection to be more prevalent for lure items that share a meaning based relationship to their targets than for lure items that share a perceptually based relationship to their targets (Odegard & Lampinen, 2005). This basic pattern would produce the decreased acceptance of conjunction lures predicted by Jones and Jacoby (2001).

However, Ghatala, Levin, Bell, & Lodico (1978) did not find this to be the case in the memory conjunction paradigm. When Ghatala et al. cued participants to think about the study item using the same meaning as it would hold in the conjunction lure, participants were more likely to commit false alarms to these conjunction lures. Increasing semantic overlap between the features used to construct the conjunction lure and the meanings that they held within the conjunction lure produced an effect opposite to the one predicted by Jones and Jacoby (2001). Why might this be? One potential reason is that the induction of semantic fluency increased the rate at which conjunction lures were accepted based on familiarity, in the absence of an increase in recollection rejection. Another potential reason for these results might be that both memory conjunction errors and familiarity increased for these items. Finally, one might assume that familiarity, memory conjunction errors and recollection rejection all three increased for these items.

Consider this third explanation in more detail. Semantically related conjunction lures would be better cues for the originally presented targets, increasing recollection rejection and therefore compensating for the increased familiarity experienced for these items. However, participants would experience memory conjunction errors at increased rates as well, producing a net increase in the acceptance of semantically related lures on a recognition memory test. Yet, why would there be an increase in memory conjunction errors?

Memory conjunction errors might increase because features that share a similar meaning may be organized into a memory unit. Recall that variables that induce a person to view perceptual features as belonging to the same unit increased rates of illusory conjunctions between features within these units. Also, similarity resulted in participants viewing features spatially distal from one another as belonging to the same perceptual unit, increasing rates of illusory conjunctions between these features. As such, semantic similarity might induce participants to view memorial features as belonging together, especially when these features are free floating.

Thus, it would be of interest to introduce a variable such as delay that should break apart the features within a trace. Now, the semantic similarity shared between the features should make it more likely that they will be inappropriately bound back together to form conjunctions that match the meaning of the targets. One might assume that under such conditions features may be equally as likely to be recombined to form targets and conjunction errors. At the same time the decreased ability of participants to directly retrieve a coherent trace for the studied materials will dampen recollection rejection. Thus, memory conjunction errors will be unopposed by recollection rejection.

Indeed, we observed semantic overlap to increase the ability of participants to use recollection rejection to reject conjunction lures (Odegard et al., 2005). Research investigating the influence of semantic overlap on recollection rejection and memory conjunction errors allows us to start to understand the relationship between recollection rejection and memory conjunction errors. Our explanation of the effect of semantic overlap makes an assumption contrary to the one made in equation 11. Specifically, we assume in this instance that recollection rejection does not necessarily trump memory conjunction errors. As such, memory conjunction errors may not necessarily be precluded by recollecting the

original context of an item. This also gets at the heart of a question proposed by Treisman and Schmidt (1982). They proposed that features even when bound into an object representation may be used to form illusory conjunctions. Thus, even when a person recalls that black was presented in blackmail, they may still feel confident that blackbird was also presented. This highlights one of the benefits of the self report technique. This approach is not hampered by the same level of assumptions as to the order of operations imposed upon the process dissociation and ROC based techniques.

To conclude, the memory conjunction paradigm allows us to understand more fully the nature of recollection. This understanding will be aided greatly by systematically utilizing manipulations proven to influence illusory conjunctions. Yet, in the process it will be important to focus some attention on distinguishing between perceptual and memorial errors. To the extent that illusory conjunctions are experienced at encoding, we would expect this to bias later memory performance. However, one might also assume, as we have throughout this chapter, that retrieval based strategies reliant upon the availability of free radicals might underlie the occurrence of memory conjunction errors.

This is yet another area that can be investigated using this paradigm. This encoding based error is similar in many respects to an Implicit Associate Response (IAR; Underwood & Reichardt, 1975). An IAR occurs when a person spontaneously thinks of semantically related items when being presented with material at study. At test this person may be presented with semantically related distractor items and falsely accept them. This false alarm may occur because the person remembers the semantic related distractor, while failing to realize that it was internally opposed to externally generated. However, unlike an IAR no amount of source monitoring will allow a person to avoid this false memory, suggesting that if this encoding type error did occur it would be a particularly insidious error to control.

Finally, the title poses an interesting question. What is the tie that binds illusory perceptions and memories? First, it appears that both perception and memory are reducible to a basic feature level. In addition, it appears that these features can become inappropriately bound together to form illusions for events that never occurred. This suggests that feature binding underlies both perception and memory. Second, it appears that illusory conjunctions and memory conjunction errors are based on similar principles. The occurrence of these errors is based on the processing of features as a unit. Features that are seen as being similar to one another are processed as a unit. Features within these units are more likely to be inappropriately bound together to form illusory perceptions and memories. From a retrieval perspective, similarity is being used to bind free radicals together and allow a person to experience the past.

REFERENCES

- Ashbridge, E., Cowey, A. & Wade, D. (1999). Does parietal cortex contribute to feature binding? *Neuropsychologia*, 37, 999-1004.
- Ashby, F. G., Prinzmetal, W., Ivry, R. & Maddox, W. T. (1996). A formal theory of feature binding in object perception. *Psychological Review*, 103, 165-192.
- Bartlett, F. C. (1932). *Remembering: A study in experimental and social psychology*. Cambridge, UK: Cambridge University Press.

- Beck, D. M. & Palmer, S. E. (2002). Top-down influences on perceptual grouping. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 1071-1084.
- Bower, G. H., Black, J. B. & Turner, T. J. (1979). Scripts in memory for text. *Cognitive Psychology*, 11, 177-220.
- Brainerd, C. J. & Reyna, V. F. (2002). Fuzzy-trace theory and false memories. *Current Directions in Psychological Science*, 11, 164-169.
- Brainerd, C. J., Reyna, V. F. & Mojardin, A. H. (1999). Conjoint recognition. *Psychological Review*, 106, 160-179.
- Brainerd, C. J., Wright, R., Reyna, V. F. & Mojardin, A. H. (2001). Conjoint recognition and phantom recollection. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 27, 307-327.
- Brainerd, C. J., Wright, R., Reyna, V. F. & Payne, D. G. (2002). Dual-retrieval processes in free and associative recall. *Journal of Memory & Language*, 46, 120-152.
- Bransford, J. D. & Franks, J. J. (1972). The abstraction of linguistic ideas: A review. *Cognition*, 1, 213-248.
- Briand, K. A. & Klein, R. M. (1989). Has feature integration theory come unglued? A reply to Tsal. *Journal of Experimental Psychology: Human Perception and Performance*, 15, 401-406.
- Broadbent, D. E. & Broadbent, M. H. (1978). The allocation of descriptor terms by individuals in a simulated retrieval system. *Ergonomics*, 21, 343-354.
- Brown, A. S. (1991). A review of the tip-of-the-tongue experience. *Psychological Bulletin*, 109, 204-223.
- Cavanagh, P., Arguin, M. & Treisman, A. (1990). Effect of surface medium on visual search for orientation and size features. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 479-491.
- Cave, K. R. & Wolfe, J. M. (1990). Modeling the role of parallel processing in visual search. *Cognitive Psychology*, 22, 225-271.
- Chalfonte, B. L. & Johnson, M. K. (1996). Feature memory and binding in young and older adults. *Memory and Cognition*, 24, 403-416.
- Chastain, G. (1982). Feature mislocalizations and misjudgments of intercharacter distance. *Psychological Research*, 44, 51-66.
- Crick, F. (1984). Function of the thalamic reticular complex: The searchlight hypothesis. *Proceedings of the National Academy of Sciences*, 81, 4586-4590.
- Eichenbaum, H. (2000). A cortical-hippocampal system for declarative memory. *Nature Reviews Neuroscience*, 1, 41-50.
- Eichenbaum, H. & Bunsey, M. (1995). On the *binding* of associations in memory: Clues from studies on the role of the hippocampal region in paired-associate learning. *Current Directions in Psychological Science*, 4, 19-23.
- Estes, W. K., Allmeyer, D. H. & Reder, S. M. (1976). Serial position functions for letter identification at brief and extended exposure durations. *Perception & Psychophysics*, 19, 1-15.
- Forbus, K. D., Gentner, D. & Law, K. (1994). MAC/FAC: A model of similarity-based retrieval. *Cognitive Science*, 19, 141-205.
- Gardiner, J. M. & Hampton, J. A., (1985). Semantic memory and the generation effect: Some tests of the lexical activation hypothesis. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 11, 732-741.

- Gardiner, J. M. & Java, R. I. (1993). Recognising and remembering. In A.F. Collins & S.E. Gathercole (Eds.), *Theories of Memory* (163-187). Hove, UK: Lawrence Erlbaum Associates.
- Garoff, R. J., Slotnick, S. D. & Schacter, D. L. (2005). The neural origins of specific and general memory: the role of the fusiform cortex. *Neuropsychologia*, 43, 847-859.
- Gathercole, S. E. & Broadbent, D. E. (1984). Combining attributes in specified and categorized target search: Further evidence for strategic differences. *Memory and Cognition*, 12, 329-337.
- Ghatala, E. S., Levin, J. R., Bell, J. A. & Lodico, M. G. (1978). The effect of semantic and nonsemantic factors on the integration of verbal units in recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 4, 647-655.
- Gonsalves, B. & Paller, K. A. (2000). Neural events that underlie remembering something that never happened. *Nature Neuroscience*, 3, 1316-1321.
- Gruppuso, V., Lindsay, D. S. & Kelley, C. M. (1997). The process-dissociation procedure and similarity: Defining and estimating recollection and familiarity in recognition memory. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 23, 259-278.
- Hannigan, S. L. & Reinitz, M. T. (2000). Influences of temporal factors on memory conjunction errors. *Applied Cognitive Psychology*, 14, 309-321.
- Hannigan, S. L. & Reinitz, M. T. (2003). Migration of objects and inferences across episodes. *Memory and Cognition*, 31, 434-444.
- Hazeltine, E., Prinzmetal, W. & Elliott, K. (1997). If it's not there, where is it: Locating illusory conjunctions. *Journal of Experimental Psychology: Human Perception and Performance*, 23, 263-277.
- Hintzman, D. L. (1988). Judgments of frequency and recognition in a multiple-trace memory model. *Psychological Review*, 95, 528-551.
- Hyman, I. E., Husband, T. F. & Billings, J. F. (1995). False memories of childhood experiences. *Applied Cognitive Psychology*, 9, 181-197.
- Hyman, I. E. & Kleinknecht, E. E. (1999). False childhood memories: Research, theory, and application. In L.M. Williams and V.L. Banyard (Eds.), *Trauma and Memory* (175-188). Thousand Oaks, CA: Sage.
- Ivry, R. B. & Prinzmetal, W. (1991). Effect of feature similarity on illusory conjunctions. *Perception & Psychophysics*, 49, 105-116.
- Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, 30, 497-514.
- Jacoby, L. L. (1996). Dissociating automatic and consciously controlled effects of study/test compatibility. *Journal of Memory and Language*, 35, 32-52.
- Jacoby, L. L. & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General*, 3, 306-340.
- James, W. (1912). *Essays in Radical Empiricism*. Lincoln, NE: University of Nebraska Press.
- Johnson, M. K. & Chalfonte, B. L. (1994). Binding complex memories: The role of reactivation and the hippocampus. In D. L. Schacter & E. Tulving (Eds.), *Memory Systems* (311-350). Cambridge, MA: The MIT Press.
- Johnson, M. K., Hashtroudi, S. & Lindsay, D. S. (1993). Source monitoring. *Psychological Bulletin*, 114, 3-28.
- Jones, T. C. & Jacoby, L. L. (2001). Feature and conjunction errors in recognition memory: Evidence for dual process theory. *Journal of Memory and Language*, 45, 82-102.

- Jones, T. C., Jacoby, L. L. & Gellis, L. A. (2001). Cross modal feature and conjunction errors in recognition memory. *Journal of Memory and Language*, 44, 131-152.
- Kahneman, D. & Treisman, A. (1984). Changing views of attention and automaticity. In R. Parasuraman & R. Davies (Eds.) *Varieties of Attention*. New York: Academic Press, 29-61.
- Kahneman, D., Treisman, A. & Burkell, J. (1983). The cost of visual filtering. *Journal of Experimental Psychology: Human Perception and Performance*, 9, 510-522.
- Keele, S. W., Cohen, A., Ivry, R., Liotti, M. & Yee, P. (1988). Tests of a temporal theory of attentional binding. *Journal of Experimental Psychology: Human Perception and Performance*, 14, 444-452.
- Khurana, B. (1998). Visual structure and the integration of form and color. *Journal of Experimental Psychology: Human Perception and Performance*, 24, 1766-1785.
- Kohler, W. (1947). *Gestalt psychology: An introduction to new concepts in modern psychology*. (First Edition). New York, NY: Liveright Publishing Corporation.
- Koriat, A., Goldsmith, M. & Pansky, A. (2000) Toward a psychology of memory accuracy. *Annual Review of Psychology*, 51, 481-537.
- Kosslyn, S. M. (2005). Mental images and the brain. *Cognitive Neuropsychology*, 22, 333-347.
- Kosslyn, S. M. & Thompson, W. L. (2003). When is early visual cortex activated during visual mental imagery? *Psychological Bulletin*, 129, 723-746.
- Kosslyn, S. M., Thompson, W. L., Kim, I. J. & Alpert, N. M. (1995). Topographical representations of mental images in primary visual cortex. *Nature*, 378, 496-498.
- Kroll, N. E. A., Knight, R. T., Metcalfe, J., Wolf, E. S. & Tulving, E. (1996). Cohesion failures as a source of memory illusions. *Journal of Memory and Language*, 35, 176-196.
- Lampinen, J. M., Faries, J. M., Neuschatz, J. S. & Toggia, M. P. (2000). Recollections of things schematic: The influence of scripts on recollective experience. *Applied Cognitive Psychology*, 14, 543-554.
- Lampinen, J. M., Meier, C., Arnal, J. A. & Leding, J. K. (2005). Compelling untruths: Content borrowing and vivid false memories. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 31, 954-963.
- Lampinen, J. M., Neuschatz, J. S. & Payne, D. G. (1998). Memory illusions and consciousness: Examining the phenomenology of true and false memories. *Current Psychology*, 16, 181-223.
- Lampinen, J. M., Neuschatz, J. S. & Payne, D. G. (1999). Source attributions and false memories: A test of the demand characteristics account. *Psychonomic Bulletin & Review*, 6, 130-135.
- Lampinen, J. M., Odegard, T. N., Blackshear, E., & Toggia, M.P. (2005). Phantom ROC. In D.T. Rosen (Ed.), *Trends in Experimental Psychology Research*. Hauppauge NY: Nova Science Publishers.
- Lampinen, J. M., Odegard, T. N. & Neuschatz, J. S. (2004). Robust recollection rejection in the memory conjunction paradigm. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 30, 332-342.
- Lampinen, J. M., Ryals, D. B. & Smith, K. (2008). Compelling untruths: The effect of retention interval on content borrowing and vivid false memories. *Memory*, 16, 149-156.
- Light, L. L. (1991). Memory and aging: Four hypotheses in search of data. *Annual Review of Psychology*, 42, 333-376.

- Loftus, E. F. (1993). The reality of repressed memories. *American Psychologist*, 48, 518-537.
- Loftus, E. F. & Pickrell, J. E. (1995). The formation of false memories. *Psychiatric Annals*, 25, 720-725.
- Mandler, G. (1980). Recognizing: The judgment of previous occurrence. *Psychological Review*, 87, 252-271.
- Marsh, R. L., Hicks, J. L. & Davis, T. T. (2002). Source monitoring does not alleviate (and may exacerbate) the occurrence of memory conjunction errors. *Journal of Memory and Language*, 47, 315-326.
- McLean, J. P., Broadbent, D. E. & Broadbent, M. H. P. (1983). Combining attributes in rapid serial visual presentation tasks. *Quarterly Journal of Experimental Psychology*, 35A, 171-186.
- Metcalf, J. (1990). Composite holographic associative recall model (CHARM) and blended memories in eyewitness testimony. *Journal of Experimental Psychology: General*, 119, 145-160.
- Mishkin, M., Ungerleider, L. G. & Macko, K. A. (1983). Object vision and spatial vision: Two cortical pathways. *Trends in Neurosciences*, 6, 414-417.
- Moscovitch, M. (1994). Memory and working with memory: Evaluation of a component process model and comparisons with other models. In D. L. Schacter & E. Tulving (Eds.), *Memory systems 1994* (269-). Cambridge, MA: The MIT Press.
- Mozer, M. C. (1983). Letter migration in word perception. *Journal of Experimental Psychology: Human Perception and Performance*, 9, 531-546.
- Noppeney, U. & Price, C. J. (2002). Retrieval of visual, auditory, and abstract semantics. *NeuroImage*, 15, 917-926.
- Odegard T. N., Koen, J. D. & Gama, J. (2008). Processing demands of rejection processes of memory. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 34, 1296-1304.
- Odegard, T. N. & Lampinen, J. M. (2004). Memory conjunction errors for autobiographical events: More than just familiarity. *Memory*, 12, 288-301.
- Odegard, T. N. & Lampinen, J. M. (2005). Recollection rejection: Gist cuing of verbatim memory. *Memory and Cognition*, 33, 1422-1430.
- Odegard, T. N., Lampinen, J. M. & Toglia, M. P. (2005). Meaning's moderating effect on recollection rejection. *Journal of Memory and Language*, 53, 416-429.
- Payne, D. G. & Blackwell, J. M. (1998). Truth in memory: Caveat emptor. In S.J. Lynn & K.M. McConkey (Eds.). *Truth in Memory*. (32-61). New York: Guilford Press.
- Payne, D. G., Neely, J. H. & Burns, D. J. (1986). The fection effect: Further tests of the lexical activation hypothesis. *Memory & Cognition*, 14, 246-252.
- Pezdek, K. & Hodge, D. (1999). Planting false childhood memories in children: The role of event plausibility. *Child Development*, 70, 887-895.
- Prinzmetal, W. (1981). Principles of feature integration in visual perception. *Perception & Psychophysics*, 30, 330-340.
- Prinzmetal, W. (1995). Visual feature integration in a world of objects. *Current Directions in Psychological Science*, 4, 90-94.
- Prinzmetal, W., Ivry, R. B., Beck, D. & Shimizu, N. (2002). A measurement theory of illusory conjunctions. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 251-269.

- Prinzmetal, W. & Keysar, B. (1989). A functional theory of illusory conjunctions and neon colors. *Journal of Experimental Psychology: General*, 118, 165-190.
- Prinzmetal, W. & Millis-Wright, M. (1984). Cognitive and linguistic factors affect visual feature integration. *Cognitive Psychology*, 16, 305-340.
- Prinzmetal, W., Treiman, R. & Rho, S. H. (1986). How to see a reading unit. *Journal of Memory and Language*, 25, 461-475.
- Rajaram, S. (1993). Remembering and knowing: Two means of access to the personal past. *Memory & Cognition*, 21, 89-102.
- Reinitz, M. T. & Hannigan, S. L. (2001). Effects of simultaneous stimulus presentation and attention switching on memory conjunction errors. *Journal of Memory and Language*, 44, 206-219.
- Reinitz, M. T. & Hannigan, S. L. (2004). False memories for compound words: Role of working memory. *Memory and Cognition*, 32, 463-473.
- Reinitz, M. T., Morrissey, J. & Demb, J. (1994). Role of attention in face encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20, 161- 168.
- Reyna, V. F. & Lloyd, F. L. (1997). Theories of false memory in children and adults. *Learning and Individual Differences*, 9, 95-123.
- Roediger, H. L. (1996). Memory illusions. *Journal of Memory & Language*, 35, 76-100.
- Roediger, H. L. & McDermott, K. B. (1995). Creating false memories: Remembering words not presented in lists. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 21, 803-814.
- Roskies, A. L. (1999). The binding problem. *Neuron*, 24, 7-9.
- Rotello, C. M. & Heit, E. (1999). Two-process models of recognition memory: Evidence for recall-to-reject? *Journal of Memory and Language*, 40, 432-453.
- Rotello, C. M. & Heit, E. (2000). Associative recognition: A case of recall-to-reject processing. *Memory & Cognition*, 28, 907-922.
- Rotello, C. M., Macmillan, N. A. & Van-Tassel, G. (2000). Recall-to-reject in recognition: Evidence from ROC curves. *Journal of Memory and Language*, 43, 67-88.
- Schacter, D. L. (2001). *The seven sins of memory: How the mind forgets and remembers*. Boston: Houghton Mifflin.
- Schacter, D. L., Norman, K. A. & Koutstaal, W. (1998). The cognitive neuroscience of constructive memory. *Annual Review of Psychology*, 49, 289-318.
- Schank, R. C. (1982). *Dynamic Memory: A Theory of Reminding and Learning in Computers and People*. New York: Cambridge University Press.
- Singer, W. (2001). Consciousness and the binding problem. In: Marijuan, Pedro C. (Ed); 2001. *Cajal and consciousness: Scientific approaches to consciousness on the centennial of Ramon y Cajal's Textura*. (p. 123-146).
- Snodgrass, J. G. & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, 117, 34-50.
- Spencer, W. D. & Raz, N. (1995). Differential effects of aging on memory for content and context: A meta-analysis. *Psychology and Aging*, 10, 527-539.
- Treisman, A. (1992). Perceiving and re-perceiving objects. *American Psychologist*, 47, 862-875.
- Treisman, A. & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, 12, 97-136.

- Treisman, A., Kahneman, D. & Burkell, J. (1983). Perceptual objects and the cost of filtering. *Perception & Psychophysics*, 33, 527-532.
- Treisman, A. & Paterson, R. (1984). Emergent features, attention, and object perception. *Journal of Experimental Psychology: Human Perception and Performance*, 10, 12-31.
- Treisman, A. & Schmidt, H. (1982). Illusory conjunctions in the perception of objects. *Cognitive Psychology*, 14, 107-141.
- Treisman, A. & Souther, J. (1986). Illusory words: The roles of attention and of top-down constraints in conjoining letters to form words. *Journal of Experimental Psychology: Human Perception and Performance*, 12, 3-17.
- Tsal, Y. (1989). Do illusory conjunctions support the feature integration theory? A critical review of theory and findings. *Journal of Experimental Psychology: Human Perception and Performance*, 15, 394-400.
- Tulving, E. (1983). *Elements of episodic memory* (First Edition). Oxford, UK: Clarendon Press.
- Underwood, B. J., Kapelak, S. M. & Malimi, R. A. (1976). Integration of discrete verbal units in recognition memory. *Journal of Experimental Psychology: Human Learning and Memory*, 2, 293-300.
- Underwood, B. J. & Reichardt, C. S., (1975). Implicit associational responses produced by words in pairs of unrelated words. *Memory and Cognition*, 3, 405-408.
- Van Essen, D. C. & Maunsell, J. H. R. (1983). Hierarchical organization and functional streams in the visual cortex. *Trends in Neurosciences*, 6, 370-375.
- Virzi, R. A. & Egeth, H. E. (1984). Is meaning implicated in illusory conjunctions? *Journal of Experimental Psychology: Human Perception and Performance*, 10, 573-580.
- Watson, J. M., Balota, D. A. & Sergent-Marshall, S. D. (2001). Semantic, phonological, and hybrid veridical and false memories in healthy older adults and in individuals with dementia of the Alzheimer type. *Neuropsychology*, 15, 254-268.
- Wheeler, M. E., Petersen, S. E. & Buckner, R. L. (2000). Memory's echo: Vivid remembering reactivates sensory-specific cortex. *Proceedings of the National Academy of Sciences*, 97, 11125-11129.
- Wolfe, J. M. & Cave, K. R. (1999). The psychophysical evidence for a binding problem in human vision. *Neuron*, 24, 11-17.
- Wolfe, J. M., Cave, K. R. & Franzel, S. L. (1989). Guided search: An alternative to the feature integration model for visual search. *Journal of Experimental Psychology: Human Perception and Performance*, 15, 419-433.
- Wolford, G. (1975). Perturbation model for letter identification. *Psychological Review*, 82, 184-199.
- Wolford, G. & Shum, K. H. (1980). Evidence for feature perturbations. *Perception & Psychophysics*, 27, 409-420.
- Yonelinas, A. P. (1997). Recognition memory ROCs for item and associative information: The contribution of recollection and familiarity. *Memory and Cognition*, 25, 747-763.
- Yonelinas, A. P. (1999). The contributions of recollection and familiarity to recognition and source-memory judgments: A formal dual-process model and an analysis of receiver operating characteristics. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 25, 1415-1434.
- Yonelinas, A. P. (2001). Consciousness, control, and confidence: The 3 Cs of recognition memory. *Journal of Experimental Psychology: General*, 130, 361-379.

-
- Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, 46, 441-517.
- Zeki, S. & Shipp, S. (1988). The functional logic of cortical connections. *Nature*, 335, 311-317.

Chapter 4

A NEW METHODOLOGY TO ASSESS INDIVIDUAL DIFFERENCES IN SPATIAL MEMORY: THE COMPUTER-GENERATED VERSION OF THE REORIENTATION PARADIGM

***Luciana Picuccia^b, Andrea Bosco^{a,*}, Alessandro O. Caffò^a,
Guido D'Angelo^a, Emanuela Soletti^a, Giulio E. Lancioni^a
and Manuela N. di Masi^a***

^a Department of Psychology, University of Bari, Piazza Umberto I, Bari, Italy

^b Institute of Psychology, University of Paris V, Vaillant,
Boulogne Billancourt Cedex, France

ABSTRACT

Gender and age are assumed to affect spatial performance. However, systematic attention to gender differences across life-span remains sparse. This paper provides an overview on behavioural changes in human reorientation as effect of gender and age. A total of 340 healthy participants, balanced by gender, were divided into three groups (166 children, 72 young adults, 102 aged adults) and engaged in a virtual version of the Reorientation Paradigm. The task consisted of a learning phase, in which participants acquired spatial information about the position of a target, and of a testing phase, in which participants searched for the hidden target. Performances of the three groups have been compared in: (a) an environment with layout information only, (b) an environment with both layout and featural information, and (c) an environment with featural information only. Accuracy in testing phase (i.e. number of correct searches) and navigation style (i.e. measured as time spent and path lengths, in both learning and testing phase) were evaluated. Results showed an age related effect in all the measures provided. On average, children and aged adults spent more time and cover longer distance with respect to young adults, in both learning and testing phase. In addition, the ability to evaluate spatial information is not completely achieved in children and tends to decrease

* Corresponding author: E-mail: a.bosco@psico.uniba.it

in aged adults. The interaction between gender and age showed that gender related differences are absent in childhood, but became considerable in adulthood and remain stable in old age. These results are in line with an explanation of gender-related differences in spatial cognition founded on the interaction between biological and environmental/cultural factors.

INTRODUCTION

Science has a deterministic approach: every event, including cognition, behaviour, decision making and action, is determined by a steady sequence of prior episodes. Accordingly, paraphrasing Murray and Kluckhohn (1953), we can assert that every human being is like all other human beings. At the same time we cannot deny that sometimes things are not so easy and every human being is like only *some other* human beings. This is the main theoretic framework of differential psychology. The leading idea is to avoid the risk to hide essential differences between persons as effect of averaging the level of their individual performances. In the modern psychological approach to individual differences, it is usually assumed that: (a) persons differ on a range of psychological attributes, (b) individual differences are assessable, and (c) individual differences help in explaining and predicting behaviour. For instance, in the realm of social behaviour we can safely predict that a large sample of Americans, would exhibit certain distinct characteristics more frequently than will a large sample of Italian balancing samples for age, gender, social class, and occupation. At the same time in the realm of cognition some basic skills and in particular age and gender are considered as important individual dimensions that should be taken into account when the researcher is interested in understanding the ability of participants in a new task. On the contrary, the averaged level of performance may mask multiple facets of the phenomenon under study and conclusions are misleading if not totally bogus. The extent to which individual differences have been studied in different research areas of cognition is related to a multitude of factors. Unquestionably, they represent a core topic in spatial cognition.

A Brief Overview on Spatial Cognition

Spatial cognition is the capacity to discover, mentally transform and use spatial information about the world in order to achieve a variety of goals, including navigating through the world, identifying and acting on an object, talking about objects in the space and using explicit symbolic representation such as maps and diagrams to communicate about the world. In spatial cognition domain, the research has been focused on two main streams: information processing of spatial ability (also known as the psychometric approach) and the encoding of environmental knowledge (e.g. Allen, Kirasic, Dobson, Long, & Beck 1996). Spatial ability is defined as the ability to generate, retain, and transform abstract visual images (Lohman, 1979). This research area has led to an improved understanding of spatial factors traditionally identified in a psychometric approach including mental rotation of abstract or concrete shapes, mazes, imagining the folding and unfolding of sheets of paper and finding hidden figures among others. These tasks are usually referred to as “small-scale” psychological testing. On the other hand, “large-scale” psychological testing is suitable to assess

environmental knowledge: the acquisition of information about the spatial attributes of physical environments. Environmental spatial tasks have taken into account the ability to learn the layout of new environments (such as rooms, buildings and towns) navigation in familiar and novel environments (real or virtual) and interpreting verbally given spatial directions (e.g. Bosco, Picucci, Caffò, Lancioni, Gyselinck 2008; Waller, Montello, Richardson, & Hegarty, 2002; Gyselinck, Picucci, Piolino & Nicolas 2006; Lawton, Charleston, & Zieles, 1996; Bosco, Sardone, Scalisi & Longoni, 1996). Nonetheless, the most typical spatial experience is to acquire information through navigation with the purpose to maintain the orientation within the environment. This aim can be accomplished as the consequence of applying several strategies. The most basic one is the *locomotor guidance* that is the ability to travel successfully in relation to a continuously detectable target, without any memory requirement (Nadel, 1990). A slightly more complex strategy is *landmark navigation*, that is, the ability to reorient with respect to a known object which requires memory for a particular landmark. *Path integration* or dead reckoning is the ability to update the distance and direction travelled from a starting point. Information for path integration might come from internal body senses such as vestibular and proprioceptive systems (Berthoz, Israel, George-Francois, Grasso & Tsuzuku, 1995) or from visual information (Srinivasan, Zang & Bidwell 1997).

The research on navigation of human and nonhuman animals has often assumed that spatial knowledge is organized as a cartographic, map-like representation, the so called *cognitive map* (Tolman, 1948; Gallistel, 1990). Cognitive maps are referred to the human aptitude for decoding, storing, recognizing, recalling spatial information and location attributes, as well as in beginning a chain of spatial actions, that is, in pursuing a route (Kitchin, Blades, & Golledge 1997). Cognitive maps might preserve spatial information such as landmarks and geometric structure of the environment; route connections, distances and directions.

In humans, constructing a spatial representation of space appears to require the acquisition of at least three kinds of knowledge (Siegel & White, 1975): landmark, route, and map-like (or survey) knowledge. Only after getting in touch with distinct cues and learning the paths between them, one can build a cognitive map (Darken & Peterson, 2002; Golledge, 1987; Sadeghian, Kantardzic, Lozitskiy, & Sheta, 2006; Siegel & White, 1975). Landmark knowledge is referred as to the ability to recognize visually the objects distributed in the space regardless their absolute or relative positions.

Route knowledge constitutes the recollection of a sequence of spatially situated action about how to get from a starting location to the next place. Survey knowledge is the *gestalt-like* memory of relationships between locations. Individuals who focus on route knowledge are considered as dependent on an egocentric way-finding strategy relating a location to a part of one's body.

Conversely, those focusing on survey knowledge are considered as applying an allocentric way-finding strategy based on an absolute frame of reference or on the spatial relations between objects in the environment. (Gramann, Muller, Eick, & Schonebeck, 2005). The ability in building cognitive maps strongly depends upon several factors reflecting individual differences such as age, sex/gender, basic abilities, preferred strategies (e.g. Devlin, 2001; Kirasic, Allen, Haggerty 1992; Nori, Grandicelli, Giusberti, 2009).

Gender Differences

The idea that there are marked differences in psychological functioning between male and female individuals is well-established in neuropsychological literature (e.g. Astur, Ortiz & Sutherland, 1998). Considering the question of gender differences in cognitive functions, spatial cognition is reported as the area presenting most differences between sexes. In order to clarify the evidence concerning this class of differences is important to keep in mind the above mentioned distinction between spatial abilities and environmental knowledge. Though a general agreement has been reached for those tasks evaluating spatial abilities, the evidence is uncertain with respect to the performance on more ecological task requiring environmental knowledge (e.g. Montello, Lovelance, Golledge & Self, 1999). Reliable differences in spatial abilities, advantaging men, have been reported in tasks such as mental rotation (e.g. Voyer, Voyer & Bryden 1995), embedded figure test (e.g. Kimura, 1996) and in all those tasks closely related to the encoding of metric aspects of spatial relationships (e.g. Iachini, Sergi, Ruggiero, Gnisci, 2005). On the other hand women outperform men on some subtest such as object arrays, recall of landmark (Levy, Astur & Frick, 2005). Moreover, a meta-analysis on visuo-spatial abilities suggest that gender differences are confined to a selective groups of ability (e.g. Hyde, 2005), and emerged specifically in those tasks requiring mental manipulation of spatial information (Vecchi & Girelli, 1998). In contrast, the research assessing gender differences in environmental knowledge has shown results ranging from a clear advantage for men (e.g. Waller, Knapp & Hunt, 2001) to a lack of differences (e.g. Brown, Lahar & Mosley, 1998).

This heterogeneity in the pattern of results might be viewed as the effect of statistical and methodological factors. Starting with the first class of factors, an important statistical issue concerns the *limitation in group size*. Usually, men and women overlapped considerably in spatial navigation tasks (e.g. Saucier, Green, Leason, MacFadden Bell, & Elias, 2002). Therefore relatively large group sizes are needed to obtain statistical differences. This effect has been observed, for instance, in the *object location memory* (e.g. Postma, Jager, Kessels, Koppeschaar & van Honk 2004). A second factor is related to the well-known *file-drawer problem* (Rosenthal, 1979; Young, Bang & Kennedy, 2004; Kennedy, 2004). Studies yielding no or unexpected effects might have not been published. One can plausibly speculate that since the leading point of view regarding gender differences in spatial tasks usually favors men, several studies showing no gender differences or, paradoxically, a female advantage might have bumped into editors / reviewers refusals. Meta-analytic approach to gender differences could partially solve this problem (e.g. Voyer, Postma, Brake and Mc Ginley, 2007) by estimating how many studies with non significant or contradictory findings would be required to offset the significance of a given effect size. Although, meta-analytic approach has been often adopted to determine the degree of the effectiveness of gender differences in spatial abilities (Voyer et al. 2007; Hyde, 2005; Hyde, 1981, Maccoby & Jacklin, 1974), no meta-analytic studies assessing gender differences in spatial navigation tasks are currently available.

With regard to methodological issues, an important role in determining gender-differences is played by the *experimental setting* adopted. Environmental knowledge is a complex process depending upon numerous basic cognitive functions. Moreover, studies in this field use a wide variety of measures that may yield unclear the most probable pattern of gender differences and may cause unsatisfactory interpretation of findings. Spatial knowledge

has been assessed in three main kind of experimental settings, that is, real environments (e.g. Tlauka, 2006), simulated environments (e.g. Waller, 2005) and maps (e.g. Coluccia, Bosco & Brandimonte 2007). According to Coluccia and Losue (2004) when navigation took place in both real (e.g. Malinowsky & Gillespie, 2001; Iachini, Ruotolo, Ruggiero, 2008; Saucier et al. 2002; Schmitz, 1997) and virtual environments (Sandstrom, Kaufman & Huettel, 1998; Waller, Knapp & Hunt, 2001; Moffat, Hampson & Hatzipantelis, 1998) women never outperformed men, but in almost half of cases gender differences did not emerge. In the latter situation gender differences emerged only in terms of spatial strategies adopted. In particular, men seemed to rely on global reference points and configurational or survey strategies. On the contrary, women showed to prefer the support of landmarks and of route strategies. Supporting this evidence, Saucier et al. (2002) asked participants to navigate toward four novel destinations in a university campus. Results suggested that men performed better in navigational task if they were provided with Euclidean information (compass directions and metric distances), whereas women performed better if they were provided with landmark information (salient landmarks and egocentric directions). At the same time, Sandstrom et al. (1998) assessing gender differences in a virtual version of Morris Water Maze task found that both men and women were able to learn the task but they differed in the extent to which they relied on particular types of cues. Men seemed to adapt more flexibly their frame of reference with respect to women. Assessing gender differences through map study (e.g. Mc Fadden, Ealse & Saucier, 2003; Coluccia & Martello, 2004; Dabbs, Chang, Strong & Milun, 1998; O' Laughlin & Brubacker, 1998; McGuinnes & Spark, 1983) the number of studies in which men performed better than women are only slightly superior to those in which gender differences do not emerge. In addition it was the only experimental setting in which exceptionally women outperform men. In particular, McGuinnes and Spark (1983) asked participants after studying a map to sketch it and found that women included more details than men. In addition, Galea and Kimura (1993) found that women recalled landmarks and streets' names better than men. No differences between sexes have been found in straight line distance estimation, map completion and time spent to learning the map (Brown et al. 1998). In summary, gender differences appear as function of *context* in which spatial information is acquired. In particular, within virtual and real navigation context gender differences rise up most frequently than in map studies. This effect could be related to the perspective of spatial mental representation directly accessible within different contexts (Montello et al. 1999). Real and virtual navigation, indeed, offers a route / egocentric (first's person) perspective, instead map provides a survey / allocentric perspective. Women compared with men might meet some obstacles in forming a survey representation starting from an egocentric perspective. Nonetheless, if the survey perspective is already available, such as in map task, gender differences are leveled off. These results might be explained in terms of troubles encountered by female participants in mentally manipulate spatial information (Vecchi & Girelli, 1998).

Another methodological issue deserving consideration in research on gender differences, concerns *task specificity*. Regardless the environmental setting employed gender differences could rise up as effect of task. They clearly emerge in pointing (e.g. Schmitzer-Torbert, 2007) and wayfinding task (e.g. Chen, Chang, & Chang, 2009) but are small and sometimes opposite to those expected in sketch map (e.g. Coluccia, Iosue, & Brandimonte 2007) and distance estimation (e.g. Coluccia & Martello 2004). Moreover, studies focused on category or coordinate relationships among objects can provide other support to the effect of task specificity on gender differences. Categorical spatial relationships refer to abstract

descriptions of the relation between objects (e.g. using words such as *above / below, outside / inside, left / right*). These spatial relationships require the verbal encoding of object locations. Coordinate relationships, on the other hand, refer to the encoding of the fine-grained, metric spatial encoding of spatial relationships among objects (i.e. the distances). The latter information seems essential in accurately reaching and grasping objects. (e.g. Kosslyn, Thompson, Gitelman & Alpert, 1998).

More recently, Astur, Tropp, Sava, Constable and Markus (2004) assessed gender differences by adopting virtual analogues of two classical paradigms in comparative research: the Morris Water Maze (MWM) and the eight-arm radial maze (RAM). These tasks can be thought as eligible instruments in evaluating coordinate and categorical encoding of spatial relationships, respectively. Results showed significant gender-related differences in MWM but not in RAM. More specifically, in RAM task participants did not need to encode spatial locations in a very precisely fashion in order to determine which arm contained the goal. On the other hand the MWM task required to acquire knowledge on both directions and distances. This interaction between the encoding of different spatial relationships and gender has been confirmed by Postma, Izendoorn and De Haan (1996). They found that men scored higher than women in object location memory tasks tapping fine-grained and metric properties of the environment, whereas there were not gender differences when the same task was arranged to involve discrete and categorical information. These results support the notion that *sexual dimorphism* in spatial memory processes reflects the multidimensional nature of tasks. (Rahman, Abrahams & Jussab 2005). Formerly, we have discussed a number of findings suggesting that differences in tasks might determine differences in gender-related performance. Coherently, one of the most influential theories on gender differences in spatial cognition assumes environmental factors as crucial in gender-related differentiation.

Environmental Factors

Usually boys and girls do not play with the same toys, do not get involved in the same activities (Newcombe, Bandura, & Taylor, 1983), and do not have the same amount of experience with spatial tasks (Baenninger & Newcombe, 1989). These factors are likely to affect spatial performance. Beanninger and Newcombe (1995) suggested as changes of gender-related roles decreased / eliminated many gender differences. Coherently, Crawford, Chaffin and Fitton (1995) also suggested a decline of gender differences in spatial abilities in the previous four decades. The environmental theories emphasize the role of contextual factors such as cultural reinforcement of stereotypical roles (Bem, 1983, 1993; Geary, 1995; Beanninger & Newcombe, 1995) and propose that spatial skills are strongly modulated by experience and learning. In this view the different level of spatial ability could be due to variable time spent in spatial activities by men and women. Usually males, since early childhood, have more experience in activities that enhance the development of spatial ability (Lawton & Morrin, 1999) such as videogames (e.g. Barnett, Vitaglione, Harper, Quachenbush, Steadmea & Waldez, 1997), LEGO-construction (e.g. Beanninger & Newcombe 1989) and team sports. According to Gaery (1995) children's games are likely to be intimately related to the development of the neurocognitive systems supporting primary forms of cognition. Playing in childhood is strongly determined by sex differences in interests, selective attention-to and imitation-of the same-sex adults' behavior (Eibl-

Eibesfeldt, 1989). Indeed, many of toys that are gender-appropriate for males involves spatial manipulation activities, in contrast, most toys that are gender-appropriate for females seem to focus on social interaction (Voyer, Nolan & Voyer, 2000). The role of experience was magnified in a series of studies (Gagnon, 1985; Benninger & Newcombe, 1989). Gagnon (1985) studied the effect of 5-hours videogame practice on undergraduate and graduate students.

Following the session of practice there was a dropping effect of gender differences in spatial visualization ability. In addition, some studies revealed that brief training could lighten gender differences on visuo-spatial tasks, usually favoring men. Nonetheless, gender differences still persisted after training in task such as mental rotation (Embretson, 1987). However, the magnitude and expression of gender differences vary across cultures and historical periods and therefore the expression is highly sensitive to contextual and cultural factors (Oliver & Hyde 1993; Rohner 1976).

In order to prove this claim several studies have examined whether spatial advantage showed by men is present across different populations. There were reports confirming gender differences in African, Asian, and Western cultures (e.g., Berry, 1966; Li, Nuttall & Zhu, 1999). However, Eastern Canadian Eskimos from the Baffin Islands do not show sex differences on a variety of spatial tasks, possibly because both men and women are responsible of hunting in an environment very poor of landmarks (Berry, 1966).

This data strongly support the effect of habits on the ontogeny of gender differences in spatial skills. However, other attempts to evaluate the influence of environmental factors in gender differences are not able to fully substantiate theories on environmental factors. In particular, Quasier-Pohl and Leheman (2002) aimed to verify if pattern of sex differences in visuo-spatial tasks may be differentially due to environmental factors such as the degree of application in technical and scientific courses of men and women. They found that performance was mainly affected by academic discipline and gender, but effect size of gender varied. It was largest with student majoring in arts, humanities and social science and smallest with those majoring in computational science.

At the same time, Vlachos, Andreou & Andreou (2003) found that psychosocial factors such as attending a specific university course may contribute to strengthening or weakening sex differences. These results revealed that gender differences could emerge at different degree as effect of experience and learning but they already exist. Baenninger and Newcombe (1995) reviewed a number of studies on the relation between spatial experiences and improvement in spatial ability. These studies have shown that although spatial improvement occurs, it occurs in men as well as in women, and therefore, does not rule out gender differences. The implications of this findings are that training may not wipe out the spatial advantage between men and women which show some sort of.

In conclusion data and experimental evidences seems to suggest that environmental theory of gender differences cannot wholly account for differences in spatial performances and furthermore that gender differences in spatial experience and behaviour seem not to be entirely driven by environmental factors. According to Casey (1996) gender-differentiated input may maintain or widen an already existing biological predisposition, rather than generate a differentiation starting from perfect parity.

Biological Factors

Sex differences in spatial skills seem to be strongly related to organization and activation of circulating hormones (e.g. Berenbaum, Korman & Leveroni, 1995; Driscoll, Hamilton, Yeo, Brooks, Sutherland, 2005). Biological hypotheses are based on the assumption that sexual hormones influence cognitive development and spatial memory (Williams, Barnett & Meck, 1990). Specifically, level of androgens affects spatial task since this class of hormones has an effect on the brain development (Burton, Henninger & Hafez, 2005). Geschwind and Galaburda (1987) suggested a curvilinear interaction between spatial skills and prenatal androgens such that optimal androgen level would be at the low end for males and high end for females. Prenatal androgens slowed left cerebral hemisphere development, allowing right hemisphere spatial skills to take the lead, with extremely high androgen levels slowing development of both left and right hemispheres. In addition, several studies support earlier development of right hemisphere in males than in females (e.g. Gratton, De Vos, Levy & Mc Clintock, 1992). Indeed, the right hemisphere has been shown to be more involved than left hemisphere in spatial task (e.g. Levine, Banich & Koch-Weser, 1988) this evidence has been hypothesized to be related to males advantages in spatial skills. The relationship between hormones and brain development has been confirmed by neuropsychological studies observing greater functional hemispheric asymmetries in males than in females (e.g. Gron, Wunderlich, Spitzer, Tomczac, Riepe, 2000). Given that the assessment of the hormonal milieu during normal gestation is rare a large amount of studies have been focused on individuals whose early hormonal histories were atypical in some way. This is the condition of girls with congenital adrenal hyperplasia (CHA). They demonstrated to prefer toys and activities that are traditionally preferred from boys (Barenbaum, 1993). Coherently, in a comparative study it was found that rats exposed in the neonatal phase to gonadal steroids (normal males and hormonally treated females) selectively attended to geometric cues when they were presented jointly with other types of cues. In particular, landmarks are overshadowed by the geometry of the room in which navigation occurred (Williams et al. 1990). Besides the effect of hormonal level in prenatal development, concentration of hormones are not stable during life-span but are part of a dynamic system varying significantly with developmental events such as puberty and cognitive decline. During puberty, levels of total and bio-available testosterone increase in men, but also gradually decrease in aged people. Coherently, biological theory postulates that gender differences in spatial tasks emerge in puberty, remain stable in adulthood and decrease in elderly. In other terms, it might be argued that another important factor affecting results on gender differences is the *age of the participants* (Voyer, Postma, Brake and Mc Gillen, 2007).

Studies on childhood. Understanding how biological factors interact and contribute to developmental outcomes is fundamental to developmental psychology. According to the biological theory, the relationship between circulating testosterone and spatial abilities has been reported in puberty (Nyborg, 1983; Hier & Crowley, 1982) but there are also inconsistent findings exhibiting gender differences in pre-pubertal children. For instance, Levine, Huttenlocher, Taylor and Langrock (1999) specified that sex differences in spatial ability may begin in the adolescence or as early as in preschool years, depending on the task. Sex differences on task involving mental rotation are more consistently reported beginning at about 8 years of age. Furthermore in 8-9-years-old children, as in adult, mental rotation has been implicated as the major source of gender differences on spatial tasks. In middle

childhood years, boys outperform girls on spatial task involving mental rotation but not on spatial task involving spatial perception. In the latter case, gender differences emerge by the age of 13-years-old (e.g. Voyer et al. 1995). In contrast with these findings, Liben et al. (2002), examining the effect of exogenously administered hormones in one clinical sample, concluded that sex hormones associated with puberty did not have a large impact on spatial performance assessed by mental rotation test, water level task and spatial visualization test. In summary, spatial abilities have sometimes been reported to vary systematically as hormonal change. Unfortunately, findings reported by one researcher are seldom replicated by another.

Although developmental course of spatial abilities has been largely investigated (even if with mixed results), few attempts in investigating the interaction between gender and age in navigation task has been made. Overman, Pate, Moore & Peuster (1996) examined the performance of children (aging 7 ± 2) in large-scale real word simulation of a dry Morris Water Maze and demonstrated significant age related differences in performance, though no sex related differences. Coherently, Lehnung et al. (1998), adopting the same spatial task, established that children can utilize an allocentric, distal landmark, place learning strategy by the age 8–10 and again no gender differences emerged. Taken together, these studies supported the biological hypothesis in which gender differences in children do not emerge. Unfortunately, these findings are ambiguous. Newhouse, Newhouse and Astur (2007), assessing biological hypothesis, found that male pre-pubertal children involved in a virtual version of MWM task, adopted spatial strategy to solve the task. In opposition, girls seemed to perform at chance level. The authors explained these results suggesting that gender differences in children navigation performance might depend on a different brain organization due to the differential exposure to prenatal sex steroid. In conclusion, mechanisms determining gender differences in spatial cognition affected by hormones are still unclear and request further investigations.

Studies on senescence. Currently, very little is known about the course of cognitive and brain sex differences across life span. Indeed, the older population is the least studied group for cognitive sex differences (Kimura, 1999), and findings are inconsistent regarding whether men and women differ in cognitive functioning and age-related cognitive decline. Some studies have indicated that the typical pattern of sex differences in spatial abilities generalizes from early adulthood to old age (e.g. Herlitz, Nilsson, & Backman, 1997) whereas other studies have claimed that sex differences do not persist into old age (e.g. Dollinger, 1995). Evidences for sex differences in the magnitude of age-related cognitive decline are also conflicting. Some studies have pointed to a greater age-related decline in men than in women (e.g. Rowe, Turcotte, & Hasher, 2004) whereas others studies have pointed to a greater decline in women than in men (e.g. Meinz & Salthouse, 1998). Finally, other studies have not found sex differences in age-related cognitive decline (e.g. Maitland, Intrieri, Schaie, & Willis, 2000). The literature on non-human animals strongly suggests a role of sex hormones in modulating cognitive function across-age, but few studies involving aged participants have been carried out. Nonetheless, comparative approach could give us some further information on this issue. Williams et al. (1990) found that providing testosterone in aged rats, spatial performance increase leveling off differences with adult rats. At the same time, Frick, Burlingame, Arters and Berger-Sweeney (1999) found, in spatial navigation task involving mice, that spatial reference memory decline begins at an earlier age in females than in males; this finding might be related to the cessation of estrous cycling. Warren and Juraska (2000) demonstrated that aged females in persistent estrus performed significantly better than both

pseudo-pregnant aged females and aged males, showing that posttestopausal hormonal status may influence the course of aging in females. An attempt in investigating gender and aging interaction has been carried out by Driscoll et al. (2003). In this study the authors compared young (age 20-39) and healthy aged adults (age > 60) in a MWM task. Saliva samples were also collected in order to check the level of circulating testosterone. According to literature assessing spatial memory in elderly (e.g. Moffat & Resnick, 2002; Bosco & Coluccia, 2004), the authors found a significant age-related deficit in performance. Despite this age-related deficit, robust sex differences favoring men did not diminish. In addition, circulating levels of testosterone predict spatial ability, even though testosterone levels significantly decrease with age. This result is consistent with emerging reports suggesting enhancement of cognitive function, including spatial ability, in healthy elderly men that received testosterone (Cherrier et al., 2001; Yaffe, Lui, Zmuda, Cauley, 2002), but also contrasting results has been found (e.g. Wolf & Kirschbaum, 2002). The difficulty to determine the cognitive effect of sex hormones in any crucial period of life, such as puberty and senescence, could be due to the fact that variation of sexual hormone level typically coincides with many other changes in the life of individuals. Furthermore, findings from the aforementioned studies are uncertain because many factors may co-vary with the hormonal one, included environmental ones.

Interaction Theory

There has been a movement in developmental psychology toward considering a complex framework in which environmental and biological factors interrelate to influence individual differences. In 1980, Petersen proposed a biopsychosocial framework for understanding gender differences in cognitive abilities. In this theory, she identified the reciprocal effects that socialization, biology, and psychology have on the development of gender differences. In her theory, she considered: (a) the sociocultural factors that affect the individuals through society, peers, and family, (b) the hormonal influences, and (c) psychological changes which occur with the development. All these factors change and interrelate across the life-span. The *interaction approach* asserts that gender differences are caused by a continuous interaction between environmental factors - based on experience - and biological factors - in terms of innate attitudes (Casey, 1996, 1999). Active biological / environmental correlations are the basis for a "bent twig" model of individual differences which was originally proposed by Sherman (1978) to explain male-female gender differences. According to her theory, boys show more marked spatial interests with respect to girls. Thus, they will tend to prefer spatial activities, such as carpentry and block play, choosing to participate in these activities when they are made available to them, and spend much more time in these activities than girls spend. This practice with spatial activities, in turn, helps to further develop these abilities, and thus augments the initial difference in ability between boys and girls. In brief, the innate predisposition to particular abilities influences the choice of particular activities. In this view, males with innate predisposition for spatial ability, actively search for spatial experience and spend more time for it than females.

The innate predisposition of males for spatial abilities depends on their particular pattern of cerebral organization, characterized by high right hemisphere lateralization (Annett, 1992, 1994 Eglinton & Annett, 2008; Smythe & Annett, 2006). According to Annett, most people inherit a right-shift factor which predisposes them to be right-handed and left-hemisphere

dominant for language. In addition, the right-shift gene carries costs for spatial ability and is expressed more strongly in females than in males. Based on Annett's theory (Annett, 1994), right-handers with all right-handed close relatives are likely to be *homozygotic* for the right-shift factor, receiving this gene from both parents. They are more likely to be strongly left-hemisphere dominant for language, to prefer verbal strategies for problem solving, and to be at risk for poor spatial ability. In contrast, right-handers with non right-handed relatives are more likely to be *heterozygotic* for this gene. According to Annett, females with the heterozygotic advantage for the right-shift gene are not as strongly left-hemisphere dominant for language, are less dependent on purely verbal strategies for problem solving, and therefore, have the potential for good spatial ability. In addition, the work of Casey and colleagues is especially noteworthy in evaluating the ways in which patterns of brain organization may interact with critical environmental variables. Casey and Brabeck (1990) correlate family handedness and spatial experience on a mental rotation task. The authors found that, among women reporting extensive mental rotation-related spatial experience, right-handed with non right-handed relatives had significantly higher mental rotation scores than did the right-handed with right-handed relatives. Another study supporting "bent-twig" theory was carried out by Casey, Nuttal, Pezaris and Benbow (1995). They argued that an important environmental variable is parental permission for cross-gender play. The authors find that parental permission to play with masculine stereotyped toys increased cross-gender role identity for women from mixed-handed families, but not for women from right-handed families. Thus, Casey's interpretation (Casey, 1996b) of the bent twig theory is that biological predisposition allows humans to benefit more from spatial experience than when such predisposition is absent. However, she also acknowledges that even when the biological predisposition is present, relevant experience is required to develop effective spatial skills. This means that spatial skills can still change in spite of biological constraints and that experience is the mediator of such changes.

The Experiment

The aforesaid findings showed that several factors may account for gender-related mixed results in action (e.g. navigation) as well as judgment-based (e.g. object location) spatial tasks. Variables such as sample size, heterogeneous experimental settings and aging could modulate gender differences in spatial performance. Conflicting results in orientation performance may be clarified involving quite large, gender-balanced, samples and adopting the same spatial task for assess gender differences across life-span. As specified above, orientation skills is a quite complex cognitive component assessed with a great variety of tasks. Discrepancies among studies could emerge simply as effect of the different task employed. In addition, studies addressing the impact of developmental factors on gender differences never include in their sample participants at different developmental stage. Therefore, the research database for this kind of studies is usually composed of behavioral data of adult participants, compared with those of children and aged adults (e.g. Choi & Silverman, 2003; Driscoll et al., 2005). Nonetheless, the impact of developmental factors has been largely recognized (e.g. Maitland, Intrieri, Schaie & Wills, 2000) but systematic attention to gender differences in environmental knowledge tasks across life-span remains sparse. In our knowledge no studies are available in which gender differences have been

assessed along three main stages of life (childhood, adulthood and old age) adopting the same spatial memory task.

The experiment of this chapter focuses on this issue. The spatial memory task adopted is a virtual version of Reorientation Paradigm (VReor) (Hermer & Spelke, 1994; Bosco et al. 2008). Virtual environment has been successfully employed in research involving children (e.g. Newhouse et al., 2007) and elderly (Moffat & Resnick, 2002). Virtual environments are particularly appropriate in spatial cognition research because allow carrying out dynamic testing and training in an ecologically valid manner, while still maintaining strict control over all the aspects of the experimental setting. In addition, it has been demonstrated that the neural basis for virtual navigation in humans has strong parallels to nonhuman animal findings (Maguire, Burgess, O'Keefe, 1999). This advantage is particularly wished in comparative studies. This is the case of Reorientation Paradigm.

The Reorientation Paradigm (RP) supports the idea that adult humans promptly solve a task of spatial searching by conjoining geometric (layout of the environment) and non geometric / featural (landmark) information after disorientation, while young children about 2-years-old (like others adult nonhuman mammals) do not (Hermer & Spelke 1996). The authors claim that young children primarily reorient themselves using the geometrical shape of the environment; instead the ability to use landmark information is reached only when spatial language (e.g. "go to the left of") has been acquired (e.g. Hermer, Moffet and Munkholm, 2001). Several studies argued that children's ability to use landmark and integrating spatial information could vary as effect of the testing environment that is: spatial layout, such as rhombic (e.g. Huttenlocher & Vasileya, 2003) and triangular environment (e.g. Hupback & Nadel, 2005); size, such as small (e.g. Hermer & Spelke, 1994) and large space (e.g. Learmonth, Nadel & Newcombe; 2002); the perspective taken, such as two-dimensional (e.g. Goteaux & Spelke, 2001) and three-dimensional environments (e.g. Gibson, Leichtaman, Kung & Simpson 2007). Little attention has been given to other possible variables conditioning orientation ability in this task, in particular individual differences. In RP research, neither gender differences have been systematically assessed nor have aged participants been never recruited. According to Cheng & Newcombe (2005), the lack of studies on gender differences in RP could be due to the size of sample not large enough to draw conclusions on gender-related spatial behaviour. In addition, from a theoretical point of view, the main aim in previous studies adopting RP with humans was evaluating differences emerging between adults and children in order to verify the flexibility and accessibility of spatial mental representations as effect of cognitive development. In order to reach this goal, a gender balanced experimental design, was not strictly necessary to this end. Nonetheless, the lack of interest in studying elderly population is probably due to the assumption that mature humans are able to rely flexibly on both geometric and landmark information. In our view, the assessment of age-related individual differences might be useful from different perspectives. With regard to gender differences, a large body of studies (e.g. Sandstrom et al. 1998) found that females relied primarily on landmark information, whereas males used both landmarks and geometric information. These differences may rise up in early childhood (e.g. Gibbs & Wilson 1999) masking the true pattern of spatial information processing, assessed by RP. In addition, the study of spatial behaviour in elderly may offer some indication on developmental processes in integrating spatial information. However, the ability to integrate different cues in the environment, such as the ability to process landmark information, could vary as a consequence of developmental processes (Hermer & Spelke 1994) and it is

reasonable to suppose that it can be compromised with aging (for a review, see Kirasic 2001). Moreover, the interaction between gender and age might be relevant in order to understand the evolution of gender differences across-life span.

In line with the latter consideration, two general hypotheses have been compared. Following the biological approach, gender-related differences should be limited / absent during childhood when the hormonal differentiation is not yet completed. They should be present in adulthood and extinct / declined during old age. On the other hand, in line with the environmental approach, there should be little, but not absent, differences between boys and girls, marked differences in young adults and more or less unchanged situation in the aged adults. Differences should advantage males. Moreover, additional hypotheses have been made on the interaction between kind of environment, age and gender, respectively. In particular, it was expected an interaction between age and type of available cue (i.e. layout or featural). According to the original hypothesis of Spelke and colleagues (1994), children would be anchored to a more archaic representation of space than adults. It promotes the use of layout and is inclined to ignore featural information. If this hypothesis is correct, children would show smaller differences in performance than the other two groups comparing situations in which landmark was available and those in which it was not. Finally, kind of environment was expected to interact with gender. Indeed, there is agreement on a larger inclination of women than men in using landmark. If this is true, females are expected to show more difficulties in solving the tasks when landmark is absent.

METHOD

Participants

Three-hundred-and-forty-five participants were originally recruited for taking part at the experiment. The data of five participants (three children and two aged adults) were not included in the subsequent analyses since they did not reach the proficiency in using the apparatus. The final experimental sample were composed of three groups: (a) One-hundred-sixty-six children (78 girls and 88 boys), ranging in age from 5 to 10 years (mean=8.1, SD=1.8), (b) Seventy-two young adults (36 women and 36 men), ranging in age from 19 to 27 years (mean=24.4, SD=2.6), (c) One-hundred-and-two aged adults (54 women and 48 men), ranging in age from 60 to 80 years (mean=67.2, SD=5.6). A part of them were under treatment for mild hypertension and age-related sleep disorders. Nonetheless it is often reported that substances used to mend these problems are safe or even have a protecting effect on cognitive performance. (e.g. Harrington, Saxby, McKeith, Wesnes & Ford, 2000; Amenta, Mignini, Rabbia, Tomassoni & Veglio, 2002; Salzman, 2008). Participants were sequentially admitted in a period of six months. Children were recruited from Primary Schools in the district of Bari (South-East Italy) and received a little gift in exchange for participating. Young adults were recruited from introductory courses of psychology at the University of Bari and received an extra course credit in exchange for participating. The aged adults were recruited in life-long learning Institutions (Third Age Universities) of the same geographical area and received a little gift for participating. The vision of all participants was normal or

corrected to normal. They took part at the experiment after they had provided their (or parents') written consent.

Apparatus and Material

Freeware software, the C-G Arena was used (Jacobs et al. 1997, 1998). A computer monitor (19" wide) displayed a colored view of an environment from the perspective of one positioned on the floor of the environment. The environment had an internal structure composed by a circular, invisible arena, in which the participants could move and explore freely the environment in a first-person perspective, controlling their movements with a joystick. The monitor did not display any image of the participant during the experiment.

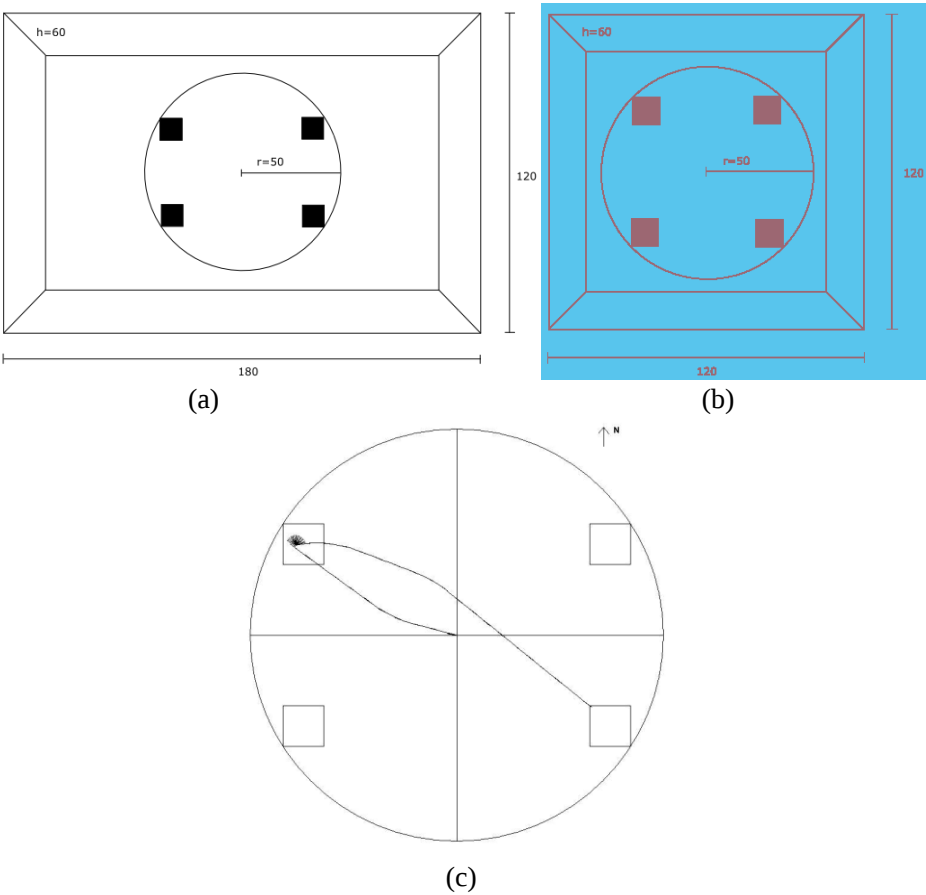


Figure 1. A bird-eye view of the virtual environment showed width, depth and height of the rectangular environment, the circular arena and its radius, and the four black response patches (a.). A bird-eye view of the virtual environment showing width, depth and height of the square environment, the circular arena and its radius, and the four black response patches (b.). A Screenshot of the output file showing the route travelled by the participant in the testing environment. The path began in the centre of the environment and finished when the participant reached the correct response patch, then the participant was trapped and teleported to the next environment.

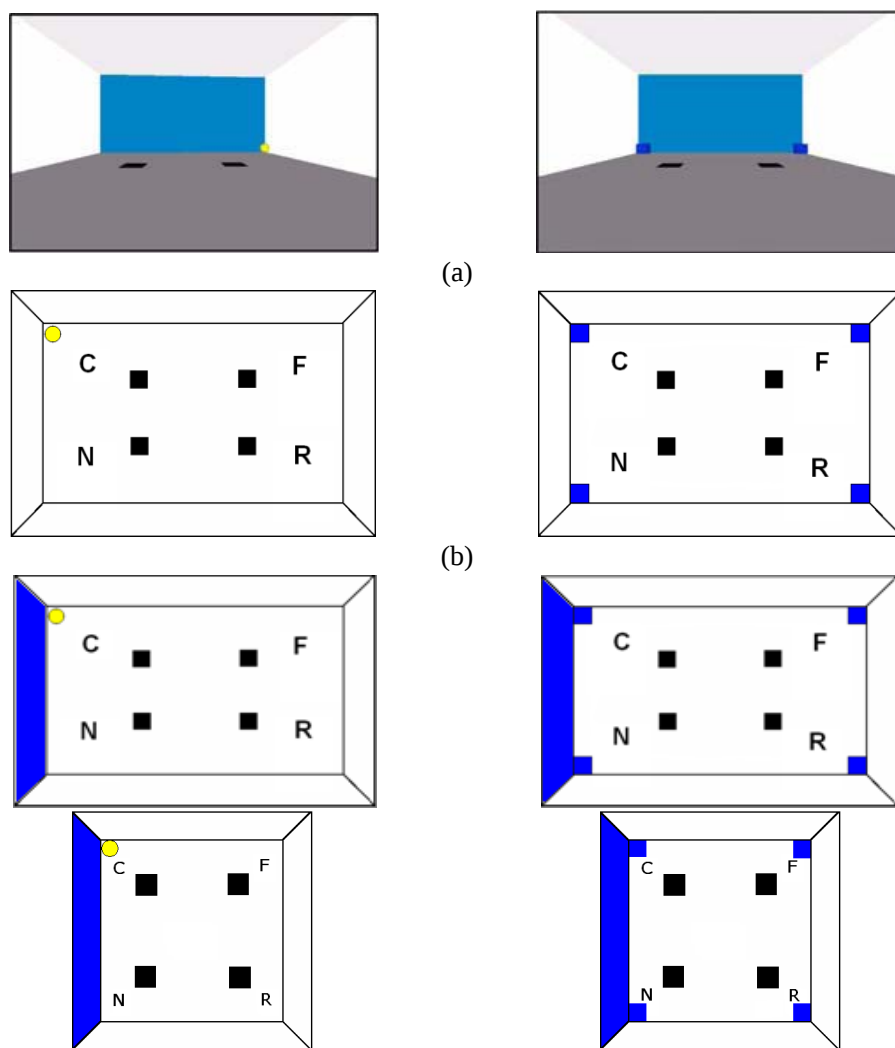


Figure 2. A first-person screenshot of learning and testing environments (blue wall condition). In the learning environment the target (a yellow sphere) is visible in one corner. In the testing environment four identical boxes are placed at the corners. One box contains the sphere (a.). A bird-eye view of all the three experimental environments, as appeared in learning and testing phases, respectively: a rectangular environment with all white walls, a rectangular environment with three white walls and one blue wall, a square environment with three white walls and one blue wall (b.).

The virtual space. The computer screen showed a perspective as if the participants were 15 units above the arena floor. This allowed the participants to feel completely comfortable with the searching task described in detail below. The arena was 50 units in radius and had a height of zero units. Consequently, participants were unable to see it; nonetheless, their movements were restricted in the arena circle. The arena held four quadrants: northeast (NE), northwest (NW), southeast (SE), and southwest (SW). The quadrants were invisible components of the computer-generated display (see Figure 1c.). Two kind of environments were created, and both of them housed an invisible arena: (a) a rectangular environment with proportion of 2:3 as proposed in the original experiment of Hermer and Spelke (1996), measuring 180 x 120 x 60 units, (b) a square environment measuring 120 x 120 x 60 units

(see Figure 1a and 1b). As it is usual in VR experiments, a correspondence between physical and a virtual space was introduced. For instance, Jacobs et al. (1998) took a length of a stride to be the equivalent of 1 m. Hartley et al. (2004) used the virtual subject's height as scale. In this study, a standard walking speed was employed. Equating the speed of the participant's view (25 units/s) to a standard walking speed (4.5 km/h) we estimated the rectangular environment to be approximately $9 \times 6 \times 3$ mt., and the square environment to be approximately $6 \times 6 \times 3$ mt. With this regard, it may be noted, however, that any strategies adopted is partially arbitrary. Three types of environments were generated. They differed both in terms of layout information and in terms of featural information: rectangular environments with four white walls (coded as L=layout information only), rectangular environments with three white walls and a blue wall on one of the short sides (coded as LF=layout and featural information), square environments with three white walls and a blue wall on one of the sides (coded as F=featural information only).

Ceiling was light grey and floor was medium grey (see Figure 2a). Experimental session counted in fifteen trials. Each trial was composed of a learning phase and a testing phase (see description below). Trials were presented in a pseudo-random order, following the subsequent scheme: LF, L, LF, LF, F, L, F, F, L, LF, F, L, LF, F, L.

The C-G learning environment. The learning environment consisted of a rectangular environment that could have all white walls, or a blue short wall, or of a square environment with one blue wall, depending on the experimental conditions. A yellow sphere, 7 units in radius, was placed in one corner (see Figure 2b). Four 10×10 units square response patches were located on the floor, inside the perimeter of the invisible arena, in relation to each corner. The response patches were leveled with the arena floor and their color was black. The use of a series of response patches was inspired by Kelly and Bishof (2005). They used the response patches in a reorientation study that employed static images depicting three-dimensional environments.

The C-G testing environment. The testing environment had the same shape and walls of the learning environment. Instead of the sphere, there were four blue identical boxes ($7 \times 7 \times 7$ units), one for each corner (see Figure 2b). The four response patches were maintained. The target corresponded to one of the patches.

Joystick and keyboard. Participants used a joystick to explore the C-G Arena. Holding the joystick forward moved the participant's view forward about 25 units/s; moving the joystick backward moved the participant's view of the same amount. Holding the joystick to the left or to the right turned the participant's view about $30\text{--}40^\circ/\text{s}$ to the left or to the right, respectively. Pressing the space bar on the computer keyboard allowed teleport from learning environment to the testing environment.

Procedure

Each participant entered into the laboratory and sat on a chair in front of a computer screen and a joystick. The eyes of the participants were approximately 50 cm from the centre of the screen. The physical FOV (Field of View) has been calculated to be 42° on the horizontal axis and 34° on vertical axis. They read and signed a consent form, then read the following written instructions:

Instruction A - What you need to do. You will start out in a learning environment, where you will see a yellow sphere in one of the four corners. Please, explore the environment using the joystick and pay attention to all the features of the environment. Walk and look until you feel comfortable, then nod your head to the research assistant: you will be teleported to the testing environment. You will find yourself in an environment identical to the previous one, but with one blue box at each corner. Your initial orientation will be randomly settled during the transitions between learning and testing environments. The yellow sphere will not change places, it will stay in the same place, but it is hidden by one blue box. Your goal is to walk around the environment and locate the corner where the sphere is placed. You should reach the black response patch on the floor, associated to the corner, only when you are reasonably convinced of your choice. You will know you have found the correct position when you hear a beep; otherwise, you should look for another corner, until you hear the sound.

Instruction B - How to move and look about. Pushing the cloche of the joystick, you can move forward. Pushing it to the left or to the right you can turn on to the left or to the right, respectively. You can withdraw from the experiment at any time with no penalty. If you have any questions about the experiment, ask the research assistant now. Once you are done with it, we will give you more details about the study.

After this reading, all participants were requested to practice with the desktop virtual environment apparatus. Prior to the start of the experiment, a training phase provided the participants the opportunity to reach an adequate level of practice with: (a) joystick, (b) procedure of the experimental session, (c) goal of the task. The training phase was carried out in order to avoid or to minimize distortions due to different level of experience when facing a virtual reality apparatus, especially in children and elderly people (Moffat & Resnick, 2002; Newhouse et al. 2007). Another technique adopted to control for this kind of bias is to ask participants how much they are confident with computer technologies. Participants answered to a short questionnaire, in order to assess their ability in the use of personal computers and videogames and console games. The use of personal computer and widespread software, such as word processing, electronic sheets etc., give us information related to familiarity with a monitor and to the degree of interaction that participants have with it. The use of videogames and console games gave us information related to familiarity with virtual environments, and with the tools for navigating in these environments. A low or high attendance in the employment of joystick, cloche, game pads, can determine relevant differences in performance in virtual navigation tasks (e.g. Gagnon, 1985).

Learning phase. After completing the training, participants entered the learning environment, facing randomly one of the four walls. In this phase, participants were explicitly requested to visit the environment looking for the yellow sphere, in order to subsequently find it in the testing environment (where the yellow sphere was hidden). When they felt comfortable with the task, they gave a signal to the research assistant, who promptly pressed the space bar and teleported the participants into the testing environment.

Virtual disorientation. During the interval between learning and testing phase, lasting 2 seconds, the computer screen was switched-off. The C-G Arena application allowed changing randomly the participants' point of view with respect to the one they had in the learning environment. This procedure induced interference in the egocentric mental representation of the relative position of the target with respect to participants' view. In other terms, in the testing environment participants had to refer to their allocentric mental representation of space: that is, the relationship between layout and featural cues (geometric

and non-geometric characteristics) of the environment and the sphere's position. This kind of interference due to changing initial orientation in testing environment will be referred to as virtual disorientation in the rest of the paper.

Testing phase. Participants' initial facing position in the testing environment was randomly settled (see above). They were requested to explore the environment to find the yellow sphere hidden in one of the four boxes. Participants knew that the yellow sphere was hidden but not moved from the original location. Thereafter, they were requested to discover the box housing the sphere by reaching the response patch corresponding to that box. If the chosen response patch was correct, participants heard a sound, and a trap captured her/him and another trial began. If the response patch was wrong, participants had to search for another corner until they had found the right one, as in typical searching tasks. Each participant was involved in three experimental conditions, each condition was composed of five trials, and for a total of fifteen trials (order of conditions was counterbalanced across participants): rectangular environment with all white walls, rectangular environment with one blue-wall near to the target, square environment with one blue-wall near to the target. Location of the target was balanced across trials.

Response coding. The output files, generated by the program, recorded a large amount of experimental data. The relevant ones for our aims are: (a) the layout of the invisible, circular arena, and the route traveled by the participants both to explore the environment in the learning phase and to reach the response patches in the testing phase, (b) the amount of time, measured in seconds, that participants spent in the learning as well as in the testing phases, (c), the path length, measured in virtual units, that participants walked both in the learning phase to explore the environment and in the testing phase to reach the correct response patch. We deemed with these five dependent variables since a very common matter in spatial cognition studies is that, particularly when the task is very basic, gender differences concerned navigation style rather than general accuracy in performance (Bosco et al. 2004; Sandstrom et al. 1998; Saucier et al. 2002).

The analysis presented here focused on the participants' first search in each trial (see Figure 1c). The first search within each trial was coded twice, (a) on-line, during the experimental session by a research assistant (blind to the experimental hypotheses) specifically trained in evaluating if a response patch was intentionally reached, and (b) off-line by means of visual inspection of an output showing the route traveled by the participants in the testing environments (see Figure 1c). A third rater assessed the disagreements (less than 2% on more than 5,000 outputs examined).

Analysis of responses in rectangular, all-white-walls environment. The responses were recorded as appropriate if the participants searched either at the correct corner "C" or at its rotationally equivalent "R" corner. Only for this type of environment, the virtual trap was associated with the response patches in the "C" corner and in the "R" corner, being both corners correct.

Analysis of responses in the rectangular, blue-wall environment. The responses were recorded as appropriate if the participants searched at the correct corner "C".

Analysis of responses in the square blue-wall environment. The responses were recorded as appropriate if the participants searched at the correct corner "C".

Dependent variables. Five dependent variables were considered here: the accuracy of the performance in terms of number of correct responses, time spent and path lengths in the learning phase, time spent and path lengths in the testing phase.

Table 1. Mean (standard errors) of dependent variables as effect of age, gender and kind of environment (Layout only, featural only, Layout + Featural), as recorded in the learning phase (Spatial Learning) and in the testing phase (Spatial Memory). Accuracy is referred to the number of correct searches (max= 5). Time spent (in seconds, calculated only for correct searches) is referred to the time needed by participants to feel confident with spatial information (Spatial Learning) or time needed to reach the response patch (Spatial Memory). Path Length (in units of space, calculated only for correct searches) is referred to the path covered to feel confident with spatial information (Spatial Learning) or path covered to reach the response patch (Spatial Memory)

	Age groups					
	Children		Young Adults		Aged Adults	
	Females	Males	Females	Males	Females	Males
Spatial Learning						
-Time spent						
Layout only	8.42 (0.19)	8.06 (0.25)	3.58 (0.26)	3.22 (0.24)	12.58 (0.70)	12.14 (0.72)
Featural only	6.37 (0.21)	6.44 (0.25)	2.01 (0.16)	1.20 (0.06)	6.71 (0.22)	7.39 (0.74)
Layout + Featural	7.18 (0.21)	6.65 (0.24)	2.25 (0.14)	1.72 (0.07)	8.62 (0.48)	8.51 (0.76)
-Path length						
Layout only	5.65 (2.04)	3.61 (1.23)	18.60 (4.70)	10.96 (2.82)	18.85 (1.52)	26.27 (5.24)
Featural only	6.32 (1.76)	5.67 (1.97)	11.47 (2.45)	7.53 (2.34)	3.55 (0.99)	9.70 (4.20)
Layout + Featural	3.64 (1.27)	5.02 (2.00)	19.66 (4.72)	8.47 (3.06)	6.08 (2.89)	10.04 (6.06)
Spatial Memory						
-Accuracy						
Layout only	3.35 (0.11)	3.47 (0.11)	4.16 (0.15)	4.22 (0.19)	3.18 (0.15)	3.73 (0.18)
Featural only	3.35 (0.17)	3.50 (0.15)	4.55 (0.17)	4.94 (0.03)	3.81 (0.17)	4.52 (0.11)
Layout + Featural	3.58 (0.16)	3.38 (0.14)	4.44 (0.11)	4.83 (0.37)	3.87 (0.16)	4.26 (0.16)
-Time spent						
Layout only	9.91 (0.71)	9.06 (0.52)	3.92 (0.44)	2.28 (0.24)	12.75 (2.17)	12.36 (0.83)
Featural only	6.21 (0.54)	6.23 (0.42)	1.90 (0.16)	1.10 (0.68)	5.90 (0.37)	5.06 (0.44)
Layout + Featural	7.60 (0.44)	6.87 (0.49)	1.64 (0.09)	1.36 (0.07)	7.33 (0.42)	7.35 (0.73)
-Path length						
Layout only	149.56 (12.49)	127.93 (7.97)	131.45 (11.91)	74.49 (7.75)	157.21 (13.81)	119.09 (11.17)
Featural only	89.57 (7.92)	87.30 (6.83)	63.67 (5.44)	40.79 (0.68)	87.19 (7.06)	62.08 (5.99)
Layout + Featural	89.87 (8.79)	86.46 (7.29)	49.03 (2.66)	41.35 (0.47)	86.37 (9.29)	59.04 (6.82)

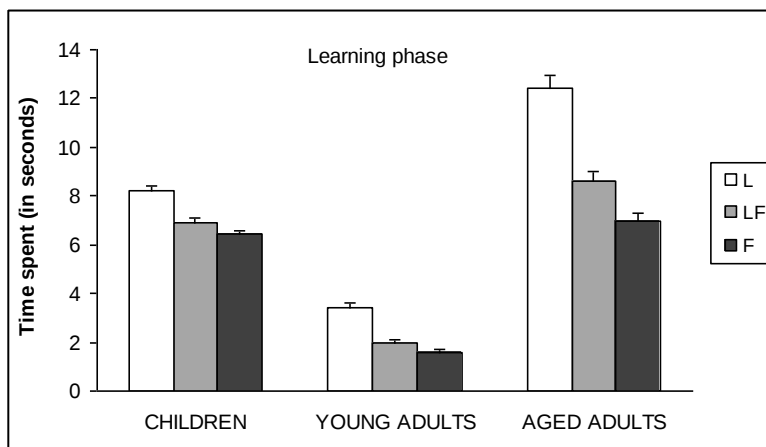


Figure 3. Learning phase. Mean times spent, standard errors on bars, for each age group (children, young adults, aged adults), and for each type of environment (white: layout information only, light grey: layout and featural information, dark grey: featural information only).

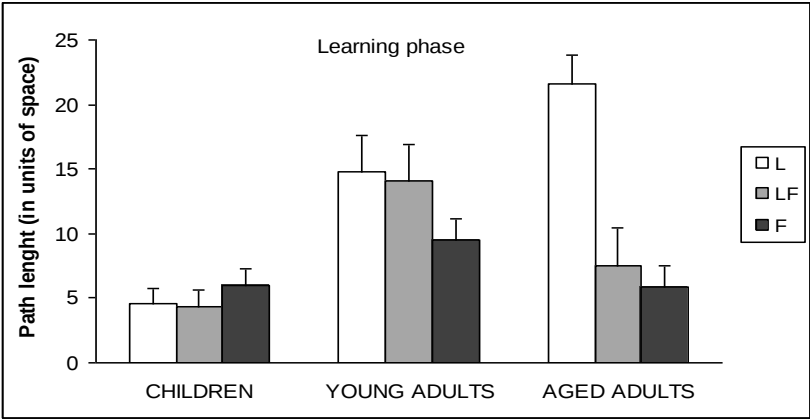


Figure 4. Learning phase. Mean path lengths, standard errors on bars, traveled to learn the characteristics of the environment for each age group (children, young adults, aged adults), and for each type of environment (white: layout information only, light grey: layout and featural information, dark grey: featural information only).

RESULTS

Table 1 showed a synopsis of performances as effect of manipulated and controlled variables.

Learning Phase

Time spent. A 2 x 3 x 3 mixed factors ANOVA was carried out on time spent to explore the learning environment. Gender (Male, Female) and age (Children, Young Adults and Aged Adults) were considered as between variables and kind of environment (Layout information only, Layout and featural Information, Featural information only) as within variable. The main effect of age emerged, $F(2, 334) = 190.05$, $p < 0.001$, $\eta_p^2 = 0.53$, $P_{rep} = 0.99$. As revealed by Scheffé post hoc test, young adults were significantly faster both than children, who, in turn, were faster than aged adults. The effect of the environment resulted significant, $F(2, 668) = 187.58$, $p < 0.001$, $\eta_p^2 = 0.36$, $P_{rep} = 0.99$. The Scheffé post hoc test highlighted that the amount of time spent on exploration was higher in the environment with layout information only, with respect to the environments presenting featural information. A significant interaction emerged between age and kind of environment, $F(2, 668) = 29.00$, $p < 0.001$, $\eta_p^2 = 0.15$, $P_{rep} = 0.99$ (see figure 3). The environment with layout information only requires more learning time for all the experimental groups, with respect to the other environments. This is particularly marked in the aged adults group.

Path lengths. A 2 x 3 x 3 mixed factors ANOVA was carried out on path lengths inside the learning environment. Gender (Male, Female) and age (Children, Young Adults and Aged Adults) were considered as between variables and kind of environment (Layout information only, Layout and featural Information, featural Information only) as within variable. The main effect of age emerged, $F(2, 334) = 9.14$, $p < 0.001$, $\eta_p^2 = 0.05$, $P_{rep} = 0.99$. As the

Scheffé post hoc test revealed, both young and aged adults engaged in longer path lengths than children. The effect of kind of environment resulted significant, $F(2, 668) = 20.24$, $p < 0.001$, $\eta_p^2 = 0.05$, $P_{rep} = 0.99$.

As the Scheffé post hoc test revealed, environments providing the layout information only required longer path lengths than the other two environments, which did not significantly differ. A significant interaction emerged between age and kind of environment, $F(2, 668) = 15.84$, $p < 0.001$, $\eta_p^2 = 0.09$, $P_{rep} = 0.99$, indicating that aged adults employ longer path lengths if the layout information only is provided (see figure 4).

Testing Phase

Accuracy. A $2 \times 3 \times 3$ mixed factors ANOVA was carried out on the number of correct responses, considering gender (Male, Female) and age (Children, Young Adults and Aged Adults) as between variables and kind of environment (Layout Only, Layout and Featural, Featural only) as within variable. The main effect of gender emerged, $F(1, 334) = 6.59$, $p < 0.05$, $\eta_p^2 = 0.02$, $P_{rep} = 0.97$, indicating that males outperformed females in the VRor task.

The effect of age was significant, $F(2, 334) = 33.5$; $p < 0.001$, $\eta_p^2 = 0.17$, $P_{rep} = 0.99$. The Scheffé post hoc test highlighted that reorientation ability increased significantly between childhood and adulthood and decrease in the old age. Nonetheless, children performed poorer than aged adults.

The effect of the kind of environment also emerged, $F(2, 668) = 19.02$, $p < 0.001$, $\eta_p^2 = 0.05$, $P_{rep} = 0.99$. The Scheffé post hoc test revealed that participants' performance was higher when they could rely on featural information (solely or in conjunction with layout), with respect to the experimental condition only the featural information as well as the featural information associated with the layout information.

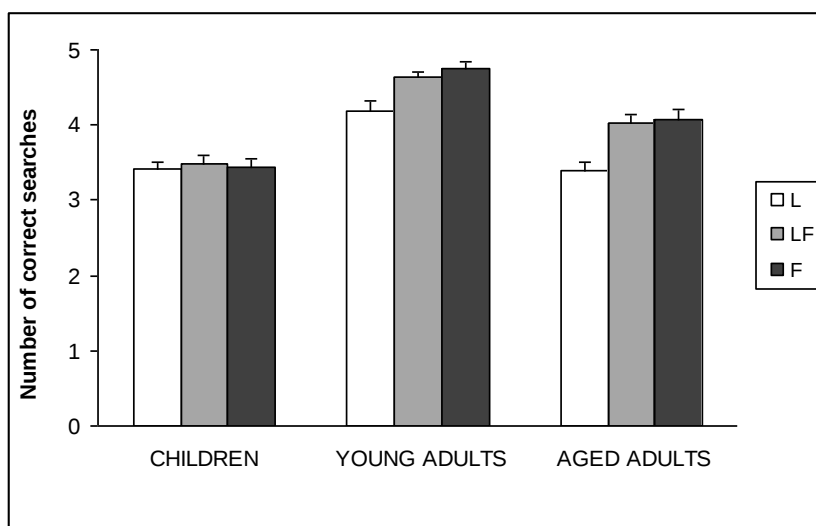


Figure 5. Mean number of correct searches, standard errors on bars, for each age group (children, young adults, aged adults), and for each type of environment (white: layout information only, light grey: layout and featural information, dark grey: featural information only).

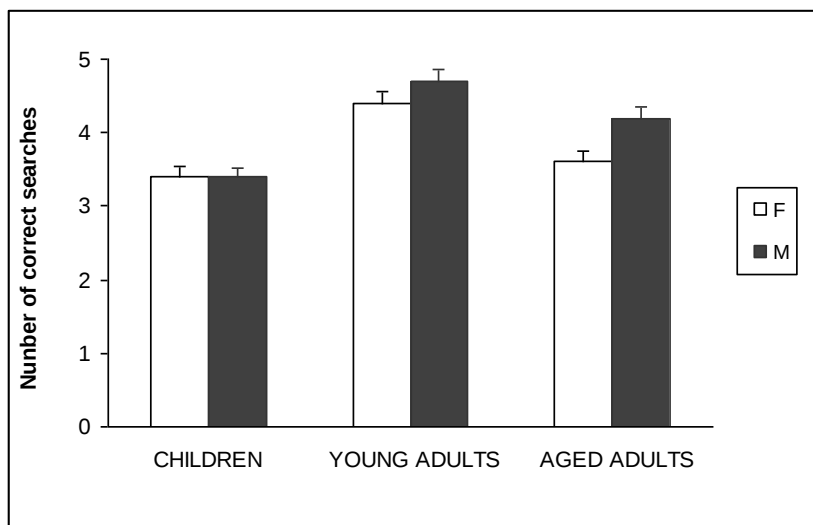


Figure 6. Mean number of correct searches, standard errors on bars, for each age group (children, young adults, aged adults), and for gender (white: females, grey: males).

A significant interaction was observed between kind of environment and age, $F(2, 668) = 5.52$, $p < 0.001$, $\eta_p^2 = 0.03$, $P_{rep} = 0.99$. The Scheffé post hoc test showed that both young and aged adults benefited of the featural information. However, children did not seem to rely on the featural information to complete the VReor task (see figure 5).

Two planned comparisons were carried out in order to evaluate the two most impressive hypotheses on interaction between gender and age. Firstly, performances of children and aged adults were pooled together and compared with that of young adults (biological hypothesis). This planned comparison did not reach the significance. Second, performances of young and old adults were pooled together and compared with that of children. This planned comparison was near to reach the significance: $F(1, 334) = 3.60$, $p = 0.058$ (see figure 6).

Time spent. A $2 \times 3 \times 3$ mixed factors ANOVA was carried out on time spent to explore the environment until the detection of the target. Gender (Male, Female) and age (Children, Young Adults and Elderly Adults) were considered as between variables and kind of environment (Layout information only, Layout and featural information, Featural information only) as within variable. The main effect of age emerged, $F(2, 334) = 95.39$, $p < 0.001$, $\eta_p^2 = 0.36$, $P_{rep} = 0.99$. As revealed by the Scheffé post hoc test, young adults were significantly faster than children as well as aged adults, who did not significantly differ. The effect of kind of environment was significant, $F(2, 668) = 65.39$, $p < 0.001$, $\eta_p^2 = 0.16$, $P_{rep} = 0.99$. The Scheffé post hoc test highlighted that the amount of time spent in searching the target was higher in the environment without the landmark with respect to the environments presenting it. A significant interaction emerged between age and kind of environment, $F(2, 668) = 9.61$, $p < 0.001$, $\eta_p^2 = 0.05$, $P_{rep} = 0.99$. Each group of participants required more time to complete the task when the layout information only was available. Nonetheless, the aforementioned effect is significantly larger in aged adults with respect to the other two age groups (see figure 7).

Path lengths. A $2 \times 3 \times 3$ mixed factors ANOVA was carried out on path lengths covered reaching the target. Gender (Male, Female) and age (Children, Young Adults and Aged

Adults) were considered as between variables and environment (Layout information only, Layout and featural information, Featural information only) as within variable. A significant effect of gender emerged, $F(2, 334) = 15.55$, $p < 0.001$, $\eta_p^2 = 0.05$, $P_{rep} = 0.99$, indicating that males engaged in shorter paths, with respect to females. The main effect of age was significant, $F(2, 334) = 14.88$, $p < 0.001$, $\eta_p^2 = 0.08$, $P_{rep} = 0.99$. The Scheffé post hoc test revealed that young adults engaged in shorter paths with respect to both aged adults and children who did not differ significantly. The effect of environment reached the significance, $F(2, 668) = 85.27$, $p < 0.001$, $\eta_p^2 = 0.2$, $P_{rep} = 0.99$.

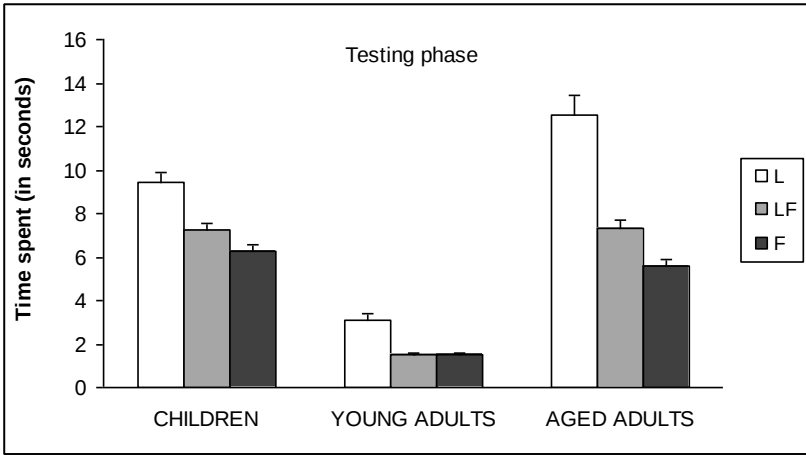


Figure 7. Testing phase. Mean times spent, standard errors on bars, for each age group (children, young adults, aged adults), and for each type of environment (white: layout information only, light grey: layout and featural information, dark grey: featural information only).

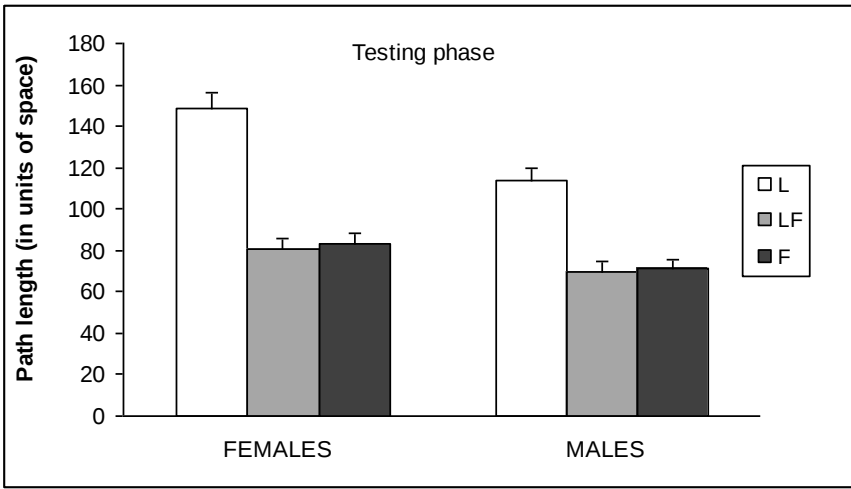


Figure 8. Testing phase. Mean path lengths, standard errors on bars, for each age group (children, young adults, aged adults), and for gender (white: females, grey: males).

Paths were longer in the environment providing the layout information only, with respect to the environments containing featural information. Finally, a significant interaction was observed between environment and gender, $F(2, 334) = 3.96$, $p < 0.05$, $\eta_p^2 = 0.01$, $P_{rep} = 0.95$, indicating that women needed longer paths to solve the task, especially when the layout information was the only available (see figure 8).

DISCUSSION

This study was aimed to provide an overview on behavioural changes in human reorientation as effect of gender and age. Three groups of healthy participants, approximately balanced by gender, were admitted to perform a navigation task in a virtual environment. Children (primary school pupils), young adults (University students) and aged adults (Third Age University students) were required to search a hidden target (previously seen during a learning phase) on the basis of layout cues (i.e. distinctive shape of the environment), featural cues (i.e. a landmark) or both. We employed the virtual version of the Reorientation Paradigm, an analogy of the test frequently used for measuring the ability to keep oriented of nonhuman animals (as well as of infants and toddlers) after that a disorientation procedure subtract them egocentric information of the environment. As aforementioned in the method paragraph, five dependent variables were considered: the accuracy of the performance in terms of number of correct responses, time spent and path lengths in the learning phase, time spent and path lengths in the testing phase.

Spatial Learning

The Performance in the learning phase (corresponding to the correct searches in the testing phase) provides useful information on the attitude of participants toward the achievement of information needed for succeed the task. Times and path lengths provide quite dissimilar implications. Spatial reorientation may be guided by the use of visual snapshots of the environment (e.g. Gillner, Weiß, & Mallot, 2008), at the same time females appeared to be particularly able to make use of these kind of approach to spatial orientation and navigation (e.g. Burgess, Spiers, & Paleologou, 2004). Coherently, participants may tend to cover long distances to observe the environment from different points of view obtaining in so far a large number of visual snapshots useful in later recognizing the target position from, virtually, any site of the environment. On the other hand, time spent in the learning phase seems directly associated with level of self confidence about spatial learning, as confirmed by studies on animal models of spatial anxiety (e.g. Ennaceur, Michalikova, & Chazot, 2009; Ennaceur, Michalikova, van Rensburg, & Chazot, 2006; Yaski, & Eilam, 2008; Yaski, & Eilam, 2008). Long time means relatively low confidence on learning, as well as a long path means the need of many snapshots to form a suitable spatial mental representation of the environment. Regarding our results, age and kind of environment showed main effects both on time spent and path length, respectively. Moreover, the aforementioned variables showed interaction effects on both the dependent variables. From the aforementioned results emerge that participants needed a longer time and a longer path to acquire information in the

environment characterized by the presence of layout only. This effect was larger in aged adults than in the other two groups. They seemed to be slightly confident and requiring many snapshots of the environment if they cannot hold on a landmark to identify the correct location of the target. On the contrary, gender seems not involved in spatial learning style, at least on the basis of our study.

Spatial Memory

The previous sub-paragraph has given to the reader some hints on learning of spatial information. They could be useful to understand the way humans approach successfully the searching task. With reference to the accuracy, main effects of gender, age and kind of the environment emerged. Males outperformed females (difference in performance is about 5%) on the overall measure of accuracy. This result has demonstrated that notwithstanding the effortlessness of the task, it seems enough sensible to capture relatively small gender-related differences. The reorientation task is based on propositional /categorical information (i.e. “target is on the left/right of the landmark”). The observed difference, favouring males, in our task seemed to contradict the results of Astur et al. (2004) and Postma et al. (1996). They found that in categorical tasks (i.e. the virtual analogy of the eight-arm radial maze and a categorical positional judgement task) males and females showed a comparable memory performance. Actually, our results contradict only apparently the aforementioned findings since in the VReor task participants have to be virtually disoriented during the retention interval. This procedure tends to modify the spatial mental representation of the environment and required to recur to an allocentric framework after that the egocentric one becomes ineffective

In addition, the skill of mentally manipulate spatial information appear to be less developed for females than for males (e.g. Vecchi & Girelli, 1998). This suggestion might be useful in explaining the main effect of gender in our results. In order to solve the task it is required a re-alignment process that involves the ability to rotate mentally spatial information. With regard to the effect of age, it has demonstrated that the ability to reorient within the environment is strongly related to cognitive development. Indeed, difference of performance between young adults and aged adults is about 12% and between young adults and children is about 21% in both cases favouring young adults. The ability to elaborate spatial information after disorientation is not completely achieved in primary school pupils (e.g. Choi & Silverman, 2003), and tends to decrease in healthy aged adults, this decrease seems quite large (e.g. Moffat & Resnick, 2002). Finally, the effect of kind of environment has shown that the absence of landmarks threatens seriously the ability of participants to reorient in the environment. More specifically, the interaction between age and kind of environment has shown that children are less able to capitalize on the presence of landmark in spite of the two groups of adults. This is in line with previous findings related to an incomplete process of integration among spatial cues: those related to the layout of the environment (or geometric cues) and those related to featural characteristics of the environment, that is, landmarks (e.g. Wang & Spelke, 2000). On the other hand, these results partially contradict previous findings. Indeed, other researchers argued that the aforementioned primacy of layout information with respect to landmarks in children is closely related to characteristics of the environment itself. Following Ratliff and Newcombe (2008) and Learmonth, Newcombe, Sheridan and Jones

(2008) an important example of these characteristics is the relative size of the enclosure used as experimental setting. They concluded that children were able to rely on landmarks if the enclosure was sufficiently wide, while their orientation is supported mainly by geometry of the environment if it is particularly small. Our experimental virtual enclosure was constructed to be perceived as quite large to stimulate a natural behavior of exploration (Bosco et al., 2008). Nonetheless, our children showed a performance that we expected in a small enclosure. It is worthy to note that the present is the first reorientation experiment on children carried out in a virtual environment. Thus, one can suppose that visual mechanisms in virtual task could be slightly different with respect to those involved in the real-world exploration. For instance, McCreary and Williges (1998) found that, in a first-person navigation task, primary school children showed an improvement of performance as effect of an extension of physical field of view. However, our physical field of view (42°H, 34°V) was comparable to the larger one involved in the aforementioned experiment. Consequently, our results on children cannot be viewed, in our opinion, as effect of a small field of view. Nonetheless, new experiments are needed in order to deeply figure out this result.

Two planned comparisons were also carried out in order to evaluate the main hypotheses described previously in the introduction paragraph. If the biological hypothesis was correct than we are inclined to suppose that performances of children and aged adults should be quite similar as compared to that of young adults. That is, small differences between boys and girls and aged men and women and large differences in young adults. Conversely, if the environmental hypothesis grasped in an appropriate manner the interaction between gender and age, then we expected that the two groups of adults may show a larger difference between men and women than children participants, nonetheless a little difference is expected also in the latter group of participants. This evaluation was carried out collapsing the performances of children and aged adults (contrasting them with that of young adults) and collapsing the performances of young and aged adults (contrasting them with that of children), respectively. Only the latter comparison was near to reach the statistical significance. Moreover, children did not show any gender effect. This result was interpreted as evidence that the experience / educational opportunities differentiating males and females on navigational tasks are effective only after a suitable amount of occurrences / occasions. At the same time the absence of gender effect in children pinpointed that biological / innate point of view on spatial navigation ability cannot be neglected (e.g. Lebine et al, 1999). On the whole, we can argue that the interaction theory seems the most suitable to get a picture of our data. Until hormones do not bring individuals in close proximity to their sexual maturity, the differentiation in terms of environmental factors does not affect the basic ability to reorient in a very simple environment.

Finally, measures of time spent and path length in the testing phase can support the interpretation of data on accuracy. Indeed, all the groups need more time to solve the tasks if only the distinctive layout is available. This difference is stronger in children than young adults and the strongest in aged adults. Path lengths covered by participants to reach the target is affected by the interaction of gender and kind of the environment. Indeed, females need of a longer path with respect to males to reach the target, only in the experimental condition in which the distinctive layout is available as single spatial cue.

As in previous studies, the age-related differences in reorientation cannot be accounted for by experimental bias as the lack of computer experience, lack of proprioceptive/vestibular hints or (in elderly people, e.g. Salthouse, 2000; Salthouse & Siedlecki, 2007) generalized

psychomotor slowness. Firstly, an adequate training and familiarization with the virtual environment were allowed until participants did not reach a proficiency criterion (see method). A study by Moffat and Resnick (2002) reported age-related decline in virtual navigation of aged compared to young people, even though participants were pre-trained to face virtual navigation. In the present study we find that children are slower and cover longer paths than young adults albeit they acknowledged the research assistants, during the pre-test questionnaire, that they are experienced with videogames. Coherently, Hamilton (2003) stated previously that the experience with videogame explained only marginally the place learning performance of young adult participants.

The lack of proprioceptive and vestibular cues due to the absence of real locomotion into the virtual environment and a restricted field of view cannot be seen as a threat to the generalization of virtual environment results to actual navigation. This is true at least for those results regarding individual differences (as stated by Driscoll et al., 2005) and in general, it has been demonstrated that neural basis for virtual navigation are strongly overlapped with those for the real one. Indeed, Ekstrom et al. (2003) directly record the activity from a large number of neurons in the human medial temporal and frontal lobes while participants explored and navigated a virtual environment. Their data demonstrate that human virtual spatial navigation is based on cells that respond to definite spatial locations and cells that respond to the visualization of a landmark as during real navigation.

As for Morris Water Maze, Reorientation task was largely used to assess spatial cognition in nonhuman animals. Unlike the former one, the latter, in our knowledge, was not yet used to understand gender and age-related navigational modifications. The diffusion of the Morris Water Maze in age-related research is due to the association between the place finding task and hippocampus both in nonhuman (Geinisman et al., 1995; Rosenzweig and Barnes, 2003) and in human animals (Moffat, Kennedy, Rodrigue, & Raz, 2007). As well as the virtual Morris Water Maze, Reorientation task may be very useful in the age-related studies since it is supported by a huge amount of comparative literature, fulfilling the need for cross-species behavioral comparisons. Nonetheless, taking into account those tasks requiring exclusively distance evaluations might neglect the other important component of spatial memory based on discrete / categorical spatial relationships. It represents a most important skill in mature humans since it is strongly connected with verbal encoding of spatial information.

CONCLUSION

The purpose of this study was to assess the reorientation ability as affected by gender and age. Our results demonstrate the effectiveness of the virtual version of reorientation task in studying gender differences in spatial ability from childhood to senescence. They can be summarized as follows: (a) the interaction hypothesis seems to grasp well our findings since gender-related differences in reorientation are negligible in childhood, became larger in adulthood and remain stable (tending to increase) in the old age. Consistently with previous findings (Gibson, Leichtman, Kung & Simpson, 2008) (b) children tend to disregard landmark information while are confident as well as adults in reorient themselves based on the layout information only. In the old age (c) people tend to be less confident of their learning particularly if the absence of a landmark cannot support them in the searching task.

Finally, (d) females need of a large number of snapshots of the environment in order to judge as correct the location of the target, in particular if the landmark is absent. The VReor paradigm seems particularly useful in evaluating general and individual differences in spatial cognition (Bosco et al., 2008, Picucci and Bosco, 2006). It allows manipulating easily those variables affecting the experimental settings such as size and shape of the environment, number and characteristics of landmarks, as well as different characteristics of procedure: retention interval, kind of task (e.g. working or reference memory), available frame of reference (i.e. allocentric and / or egocentric). The forthcoming applications might be vary. Firstly, VReor can be a basic instrument to evaluate the ability to reorient in the environment after that a perturbation of egocentric frame of reference is set up. Recently, the need for specific instruments evaluating topographical orientation is strongly felt. For instance, Iaria, Palermo, Committeri & Barton (2009) asked to young and older participants to solve a navigational task in a virtual environment designed to assess the use of cognitive map. Their results suggest that the decreased efficacy in both forming and using cognitive maps significantly contributed to the age-related decline in orientation skills. Morganti, Gaggioli, Strambi, Rusconi & Riva (2007, 2006) compared virtual reality assessment with a more classical neuropsychological battery in evaluating orientation in brain injured people and demonstrating its reliability. Moreover, virtual versions of spatial cognition paradigms might be useful in promoting specific interventions for enhance orientation skills. The interaction theory argued that biological predisposition allows humans to benefit more from spatial experience than when such predisposition is absent. Even when the biological predisposition is present, relevant experience is required to develop effective spatial skills. This means that spatial skills might elude biological constraints and experience is the mediator to success. Nonetheless, examples of specific intervention on topographical disorientation are very sparse. Brunsdon, Nickels, Coltheart, & Joy (2007) described a treatment of topographical disorientation in CA a 6-years-old child. Davis & Coltheart (1999) reported a single case study of rehabilitation of topographical disorientation in KL a 46-years-old adult. A difficulty in rehabilitating these persons is represented by the need to customize the intervention involving familiar places and other physical environments under controlled experimental condition. Coherently with the latter considerations virtual environments seem to comply with the need to provide frequent and experimentally controlled experiences of navigation to people showed topographical disorientation. Recently, the employment of virtual environment in training programs has been successfully demonstrated by Iaria, Bogod, Fox and Barton (2009) examining the first case of a woman showing topographical disorientation in the absence of brain lesions. Intensive overtraining with a simplified virtual environment had strongly increased her ability to form cognitive map of the environment. This single case sheds lights on the need to use virtual environments in spatial cognition intervention. In this view, the knowledge of individual differences related to those virtual navigational experiences allows to better tailoring interventions on topographical orientation disorder taking into account specificity of each person in terms of cognitive prerequisites, actual abilities and preferred strategies.

ACKNOWLEDGMENTS

This research was supported by a grant of the University of Bari (Ateneo 2008) to the Authors.

REFERENCES

- Allen, G., Kirasic, K., Dobson, S., Long, R. & Beck, S. (1996). Predicting Environmental Learning From Spatial Abilities: An Indirect Route. *Intelligence*, 22, 327-355.
- Amenta, F., Mignini, F., Rabbia, F., Tomassoni, D., Veglio, F. (2002). Protective effect of anti-hypertensive treatment on cognitive function in essential hypertension: Analysis of published clinical data. *Journal of Neurological Sciences*, 203, 147-151.
- Annett, M. (1992). Spatial ability in subgroups of left- and right- handers. *British Journal of Psychology*, 83, 493-515.
- Annett, M. (1994). Handedness as a continuous variable with dextral shift: Sex, generation and family handedness in subgroups of left and right handers. *Behavioral Genetics*, 24, 51-63.
- Astur, R. S., Ortiz, M. L. & Sutherland, R. J. (1998). A characterization of performance by men and women in a virtual Morris water task: A large and reliable sex difference. *Behavioural Brain Research*, 93, 185-190.
- Astur, R. S., Tropp, J., Sava, S., Constable, R. T. & Markus, E. J. (2004). Sex differences and correlations in a virtual Morris water task, a virtual radial arm maze, and mental rotation. *Behaviour and Brain Research*, 151, 103- 115.
- Baenninger, M. & N. Newcombe. (1995). Environmental input to the development of sex related differences in spatial and mathematical ability. *Learning and Individual Differences*, 7, 363-379.
- Baenninger, M. & Newcombe, N. (1989). the role of experience in spatial test performance: a meta-analysis. *Sex Roles*, 20, 327-344.
- Barnett, M. A., Vitaglione, G. D., Harper, K. K. G., Quakenbush, S. W., Steadman, L. A. & Valdez, B. S. (1997). Late adolescents' experiences with hand attitudes toward videogames. *Journal of Applied Social Psychology*, 27, 1316-1334.
- Bem, S. L. (1983). Gender schema theory and its implications for child development: Raising gender aschematic children in a gender-schematic society. *Signs: Journal of Women in Culture and Society*, 8, 598-616.
- Berenbaum, S. A. (1993). *Do early hormones interact with early experiences to affect spatial ability?* Paper presented at the meeting of the Society for Research in Child Development, New Orleans, LA.
- Berenbaum, S. A., Korman, K., Leveroni, C. (1995), Early hormones and sex differences in cognitive abilities, *Learning and Individual Differences*, 7, 303-21.
- Berry, J. W. (1966). Emne and Eskimo perceptual skills. *International Journal of Psychology*, 1, 207-229.
- Berthoz, A., Israël, I., Georges-François, P., Grasso, R. & Tsuzuku, T. (1995). Spatial memory of body linear displacement. What is being stored? *Science*, 269, 95-98.

- Bosco, A. & Coluccia, E. (2004). Assessing age differences in spatial orientation tasks following map study. *Imagination, Cognition and Personality*, 23, 233-240.
- Bosco, A., Longoni, A. M. & Vecchi, T. (2004). Gender effects in spatial orientation: cognitive profiles and mental strategies. *Applied Cognitive Psychology*, 18, 519-532.
- Bosco A., Picucci L., Caffo' A., Lancioni G.E. & Gyselinck V. (2008) Assessing human reorientation inside virtual reality environments: The role of working memory components and task characteristics. *Cognitive Processing*, 9, 299-309.
- Bosco, A., Sardone, L., Scalisi, T. G. & Longoni, A. M. (1996). Spatial models derived from verbal descriptions of fictitious environments: The influence of study time and the individual differences in visuo-spatial ability. *Psychologische Beitrage*, 38, 451-466.
- Brown, L. N., Lahar, C. J. & Mosley, J. L. (1998). Age and gender related differences in strategy use for route information. A map present direction giving paradigm. *Environment and Behavior*, 30, 123-143.
- Brunsdon, R., Nickels, L., Coltheart, M. & Joy, P. (2007). Assessment and treatment of childhood topographical disorientation: A case study. *Neuropsychological Rehabilitation*, 17, 53-94.
- Burgess, N., Spiers, H. J. & Paleologou, E. (2004). Orientational manoeuvres in the dark: Dissociating allocentric and egocentric influences on spatial memory. *Cognition*, 94, 149-166.
- Burton, L. A., Henninger, D. & Hafetz, J. (2005). Gender differences in relations of mental rotation, verbal fluency, and SAT scores to finger length ratios as hormonal indexes. *Developmental Neuropsychology*, 28, 493-505.
- Casey, M. B. (1996). Understanding individual differences in spatial ability within females: A nature/nurture interactionist framework. *Developmental Review*, 16, 241-260.
- Casey, M. B. (1996b). Gender, sex, and cognition: considering interrelationship between biological and environmental factors. *Learning and Individual Differences*, 8, 39-53.
- Casey, M. B., Brabeck, M. M. & Nuttal, R. (1995). As the twig is bent: The biology and socialization of gender roles in women. *Brain and Cognition*, 27, 237-246.
- Casey, M. B. & Brabeck, M. M., (1990). Women who excel on a spatial task: Proposed genetic and environmental factors. *Brain and Cognition*, 12, 73-84.
- Casey, M. B., Nuttal, R., Pezaris, E. & Benbow, C. (1995). The influence of spatial ability on gender differences in mathematics college entrance test scores across diverse samples. *Developmental Psychology*, 31, 679-705.
- Chance, S. S., Gaunet, F., Beall, A. & Loomis, J. M. (1998). Locomotion mode affects the updating of objects encountered during travel: the contribution of vestibular and proprioceptive inputs to path integration. *Presence*, 7, 168-178.
- Chen, C.-H., Chang, W.-C., and Chang, W.-T. (2009). Gender differences in relation to wayfinding strategies, navigational support design, and wayfinding task difficulty. *Journal of Environmental Psychology*, 29, 220-226.
- Cheng, K. & Newcombe, N. S. (2005). Is there a geometric module for spatial orientation? Squaring theory and evidence. *Psychonomic Bulletin & Review*, 12, 1-23.
- Cherrier, M.M., Asthana, S., Plymate, S., Baker, L., Matsumoto, A.M., Peskind, E., Raskind, M.A., Brodtkin, K., Bremner, W., Petrova, A., LaTendresse, S., Craft, S. (2001). Testosterone supplementation improves spatial and verbal memory in healthy older men. *Neurology*, 57, 80- 88.

- Choi, J. & Silverman, I., (2002). The relationship between testosterone and route-learning strategies in humans. *Brain and Cognition*, 50, 116–120.
- Coluccia, E., Bosco, A. & Brandimonte, M. A. (2007). The role of visuo-spatial working memory in map learning: new findings from a map drawing paradigm. *Psychological Research*, 71, 359–372.
- Coluccia, E. & Louse, G. (2004). Gender difference in spatial orientation: a review. *Journal of Environmental Psychology*, 24, 329–340.
- Coluccia E., Iosue G. & Brandimonte M. A. (2007). The relationship between map drawing and spatial orientation abilities: New findings from a study on gender differences. *Journal of Environmental Psychology*, 27, 135–144.
- Coluccia, E. & Martello, A. (2004). Il ruolo della memoria di lavoro visuo-spaziale nell'orientamento geografico: uno studio correlazionale. *Giornale Italiano di Psicologia*, 3, 523–552.
- Crawford, M., Chaffin, R. & Fitton, L. (1995). Cognition in social context. *Learning and Individual Differences*, 7, 341–362.
- Dabbs, J. M., Chang, E. L., Strong, R. A. & Milun, R. (1998). Spatial ability, navigation strategy, geographic knowledge among men and women. *Evolution and Human Behavior*, 19, 89–98.
- Darken, R. P. & Peterson, B. (2002). *Spatial Orientation, Wayfinding and Representation*. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
- Davis, S. J. C. & Coltheart, M. (1999). Rehabilitation of topographical disorientation: An experimental single case study. *Neuropsychological Rehabilitation*, 9, 1–30.
- Devlin, A. S. (2001). *Mind and maze: Spatial cognition and environmental behaviour*. Westport, CT: Praeger.
- Dollinger, S. M. C. (1995). Mental rotation performance: age, sex, and visual field differences. *Developmental Neuropsychology*, 11, 215–222.
- Driscoll, I., Hamilton, D. A., Yeo, R. A., Brooks, W.M. & Sutherland, J. R. (2005). Virtual navigation in humans: the impact of age, sex and hormones on place learning. *Hormones and Behavior*, 47, 326–335.
- Eglinton, E. & Annett, M. (2008). Good phonetic errors in poor spellers are associated with right-handedness and possible weak utilisation of visuospatial abilities. *Cortex*, 44, 737–745.
- Eibl-Eibesfeldt, I. (1989). *Human ethology*. New York: Aldine de Gruyter. *Ethos*, 4, 57–72.
- Ekstrom, A. D., Kahana, M. J., Caplan, J. B., Fields, T. A., Isham, E. A., Newman, E. L., Fried, I. (2003). Cellular networks underlying human spatial navigation. *Nature*. 425, 184–187.
- Embretson, E. (1987). Improving the measurement of spatial aptitude by dynamic testing. *Intelligence*, 11, 333–358.
- Ennaceur, A., Michalikova, S. & Chazot, P. L. (2009). Do rats really express neophobia towards novel objects? Experimental evidence from exposure to novelty and to an object recognition task in an open space and an enclosed space. *Behavioural Brain Research*, 197, 417–434.
- Ennaceur, A., Michalikova, S., van Rensburg, R. & Chazot, P. L. (2006). Models of anxiety: Responses of mice to novelty and open spaces in a 3D maze. *Behavioural Brain Research*, 174, 9–38.

- Frick, K. M., Burlingame, L. A., Arters, J. A. & Berger-Sweeney, J. (2000). Reference memory, anxiety and estrous cyclicity in mice are affected by age and sex. *Neuroscience*, 95, 293–307.
- Gagnon, D. (1985). Videogames and spatial skills: an exploratory study. *Educational Communication and Technology Journal*, 33, 263–275.
- Galea, L. A. M. & Kimura, D. (1993). Sex differences in route learning. *Personality and Individual Differences*, 14, 53–65.
- Gallistel, C. R. (1990). *The organization of learning*. Cambridge, MA: MIT Press.
- Geary, D. C. (1995). Sexual selection and sex differences in spatial cognition. *Learning and Individual Differences*, 7, 289–301.
- Geschwind, N. & Galaburda, A. M. (1987). *Cerebral lateralization*. Cambridge, MA: Bradford Books/MIT Press.
- Gibbs, A. C. & Wilson, J. F. (1999). Sex differences in route learning by children. *Perceptual and Motor Skills*, 88, 590–594.
- Gibson B. M., Leichtman, M. D., Kung, D. A. & Simpson, M. J. (2007). Use of landmark features and geometry by children and adults during a two-dimensional search task. *Learning and Motivation*, 38, 89–102.
- Gillner, S., Weiß, A. M. & Mallot, H. A. (2008). Visual homing in the absence of feature-based landmark information. *Cognition*, 109, 105–122.
- Golledge, R. (1987). *Environmental Cognition*. In D. Stokols; Altman; and E. Wilhelms (eds): *Handbook of Environmental Psychology*. New York: John Wiley and Sons, pp.131–174.
- Gouteux, S. & Spelke, E. S. (2001). Children's use of geometry and landmarks to reorient in an open space. *Cognition*, 81, 119–148.
- Gramann, K., Müller, H., Eick, E. & Schönebeck, B. (2005). Evidence of separable spatial representations in a virtual navigation task. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 1199–1223.
- Gratton, M. P., De Vos, E., Levy, J. & McClintock, M. (1992). Asymmetric action in the human newborn: Sex differences in patterns of organization. *Child Development*, 63, 273–289.
- Gron, G., Wunderlich, A. P., Spitzer, M., Tomczak, R. & Riepe, M. W. (2000). Brain activation during human navigation: Gender-different neural networks as substrate of performance. *Nature Neuroscience*, 3, 404–408.
- Gyselinck, V., Picucci, L., Nicolas, S. & Piolino, P. (2006). Construction of spatial mental model from a verbal description or from navigation in a virtual environment. *Cognitive Processing*, 7, 46–48.
- Hamilton, D. A. & Sutherland, R. J. (1999). Blocking in human place learning: evidence from virtual navigation. *Psychobiology* 27, 453–461.
- Harrington, F., Saxby, B. K., McKeith, I. G., Wesnes, K. & Ford, G. A. (2000). Cognitive performance in hypertensive and normotensive older subjects. *Hypertension*, 36, 1079–1082.
- Herlitz, A., Nilsson, L.-G. & Bäckman, L. (1997). Gender differences in episodic memory. *Memory & Cognition*, 25, 801–811.
- Hermer, L. & Spelke, E. (1994). A geometric process for spatial reorientation in young children. *Nature*, 370, 57–59.

- Hermer L. & Spelke E. (1996). Modularity and development: the case of spatial reorientation. *Cognition*, 61, 195–232.
- Hermer-Vazquez, L., Moffet, A. & Munkholm, P. (2001). Language, space, and the development of cognitive flexibility in humans: The case of two spatial memory tasks. *Cognition*, 79, 263–299.
- Hamilton, D. A., Kodituwakku, P., Sutherland, R. J. & Savage, D. D. (2003). Children with Fetal Alcohol Syndrome are impaired at place learning but not cued-navigation in a virtual Morris water task. *Behavioural and Brain Research*, 143, 85–94.
- Hier, D. B. & Crowley, W. F. (1982). Spatial ability in androgen-deficient men. *New England Journal of Medicine*, 306, 1202–1205.
- Hupbach, A. & Nadel, L. (2005). Reorientation in a rhombic environment: no evidence for an encapsulated geometric module. *Cognitive Development*, 20, 279–302.
- Huttenlocher, J. & Vasilyeva, M. (2003). How toddlers represent enclosed spaces. *Cognitive Science*, 27, 749–766.
- Hyde, J. S. (1981). How Large Are Cognitive Gender Differences? A Meta-Analysis Using ω^2 and d . *American Psychologist*, 36, 892–901.
- Hyde, J. S. (2005). The gender similarities hypothesis. *American Psychologist*, 60, 581–592.
- Iachini, T., Ruotolo, F., and Ruggiero, G. (2008). The effects of familiarity and gender on spatial representation. *Journal of Environmental Psychology*, 29, 227–234.
- Iachini, T., Sergi, I., Ruggiero, G. & Gnisci, A. (2005). Gender differences in object location memory in a real three-dimensional environment. *Brain and Cognition*, 59, 52–59.
- Iaria, G., Bogod, N., Fox, C.J., B & Barton, J.J.S. (2009). Developmental topographical disorientation: Case one. *Neuropsychologia*, 47, 30–40.
- Iaria, G., Palermo, L., Committeri, G., & Barton, J. J. (2009). Age differences in the formation and use of cognitive maps. *Behavioural Brain Research*, 196, 187–91.
- Jacobs, W. & Nadel, L. (1998). Neurobiology of reconstructed memory. *Psychology of Public Policy and Law*, 4, 1–25.
- Kelly D. M. & Bischof, W. F. (2005). Orienting in images of a 3-D environment. *Experimental of Psychological Human Perception and Performance*, 31, 1391–1403.
- Kimura, D. (1996). Sex, sexual orientation and sex hormones influence human cognitive function. *Current Opinion in Neurobiology*, 6, 259–263.
- Kimura, D. (1999). *Sex and cognition*. New York: MIT Press.
- Kirasic, K. C., Allen, G. L. & Haggerty, D. (1992). Age-Related Differences in Adults' Macrospace Cognitive Processes, *Experimental Aging Research* 18, 33–39.
- Kirasic, K. C. (1991). Spatial cognition and behavior in young and elderly adults: implications for learning new environments. *Psychological Aging*, 6, 10–18.
- Kitchin, R. M., Blades, M. & Golledge, R. G. (1997). Relations between psychology and geography. *Environment and Behavior*, 29, 554–573.
- Kosslyn, S. M. (1994). *Image and brain: The resolution of the imagery debate*. Cambridge, MA: MIT Press.
- Kosslyn, S. M., Thompson, W. L., Gitelman, D. R., and Alpert, N. M. (1998). Neural systems that encode categorical vs. coordinate spatial relations: PET investigations. *Psychobiology*, 26, 333–347.
- Lawton, C. A., Morrin, K. A. (1999). Gender differences in pointing accuracy in computer simulated 3D mazes. *Sex Roles*, 40, 73–92.

- Lawton, C. A., Charleston, S. I. & Zieles, A. S. (1996). Individual and gender related differences in indoor wayfindings. *Environment and Behavior*, 28, 204–219.
- Learmonth, A. E., Nadel, L. & Newcombe, N. S. (2002). Children's use of landmarks: Implications for modularity theory. *Psychological Science*, 13, 337–341.
- Learmonth, A. E., Newcombe, N. S., Sheridan, N. & Jones, M. (2008). Why size counts: Children's spatial reorientation in large and small enclosures: Paper. *Developmental Science*, 11, 414–426.
- Lehning M., Lepow B., Friege L., Herzog A., Ferstl R. & Mehdorn M. (1998). Development of spatial memory and spatial orientation in preschoolers and primary school children. *British Journal of Psychology*, 89, 463–480.
- Levine, S. C. , Banich, M. T. & Koch-Weser, M. (1988). Face recognition: A general or specific right hemisphere capacity? *Brain and Cognition*, 8, 303–325.
- Levine, S. C., Huttenlocher, J., Taylor, A. & Langrock, A. (1999). Early sex differences in spatial skill. *Developmental Psychology*, 35, 940–949.
- Levy, L. J., Astur, R. & Frick K. M. (2005). Men and Women differ in Object Memory but not performance of a Virtual Radial maze. *Behaviour Neuroscience*, 119, 853–862
- Li, C., Nuttall, R. L. & Zhu, W. (1999). Writing Chinese characters and success on mental rotation test. *Perceptual and Motor Skills*, 88, 1261–1270.
- Liben, L. S., Susman, E. J., Frinkelstein J. W., Chinchilli, V. M., Kunselman, S., Schwab, J., Dubas, J. S., Demers, L. M., Lookingib, G., D'Arcangelo, M. R., Krogh, H.R., Kulin H.E. (2002). The Effects of Sex Steroids on Spatial Performance: A review and an Exerimental Clinical Investigation. *Developmental Psychology*, 38, 236–253.
- Lohman, D. (1979). *Spatial abilities: a review and reanalysis of the correlation literature. (technical report 8, aptitude research)*. Stanford, CA: Stanford University, School of Education.
- Lorenz, C. A. & Neisser, U. (1986). *Ecological and psychometric dimension of spatial ability*. Atlanta, GA: Emory Cognition Project, Emory University.
- Maccoby, E. E. & Jacklin, C. N. (1974). *The psychology of sex differences*. Stanford, CACA: Stanford University Press.
- Maguire, E. A., Burgess, N. & O'Keefe, J. (1999). Human spatial navigation: cognitive maps, sexual dimorphism, and neural substrates. *Current Opinion in Neurobiology*, 9, 171– 177.
- Maitland, S. B., Intrieri, R. C., Schaie, K. W. & Willis, S. L. (2000). Gender differences and changes in cognitive abilities across the adult life span. *Aging, Neuropsychology, and Cognition*, 7, 32–53.
- Malinowski, J. C. & Gillespie, W. T. (2001). Individual differences in performance on a large scale, real word wayfinding task. *Journal of Environmental Psychology*, 21, 73–82.
- McCreary, F. A. & Williges, R. C. (1998). Effects of age and field-of-view on spatial learning in an immersive virtual environment. *Proceedings of the Human Factors and Ergonomics Society*, 2, 1491–1495.
- McGuinness, D. & Sparks, J. (1983). Cognitive style and cognitive maps: sex differences in representations of a familiar terrain. *Journal of Mental Imagery*, 7, 91–100.
- Meinz, E. J. & Salthouse, T. A. (1998). Is age kinder to females than to males? *Psychonomic Bulletin & Review*, 5, 56–70.
- Moffat, S. D., Hampson, E. & Hatzipantelis, M. (1998). Navigation in a “virtual” maze: Sex differences and correlation with psychometric measures of spatial ability in humans. *Evolution and Human Behavior*, 19, 73–87.

- Moffat, S. D., Resnick, S. M. (2002). Effects of age on virtual environment place navigation and allocentric cognitive mapping. *Behavioural Neuroscience*, 116, 851–859.
- Montello, D. R., Lovelace, K. L., Golledge, R. G. & Self, C. M. (1999). Sex-related differences and similarities in geographic and environmental spatial abilities. *Annals of the Association of American Geographers*, 89, 515–534.
- Morganti, F., Gaggioli, A., Strambi, L., Rusconi, M. L. & Riva, G. (2007). A virtual reality extended neuropsychological assessment for topographical disorientation: A feasibility study. *Journal of NeuroEngineering and Rehabilitation*, 4, 112–128.
- Morganti, F., Gaggioli, A., Strambi, L., Rusconi, M. L. & Riva, G. (2006). Computer-enhanced route and survey spatial knowledge assessment in clinical neuropsychology. *IEEE International Workshop on Virtual Rehabilitation: August 2006; New York 2006*:110–115.
- Murray, H. A., Kluckhohn, C. (1953). *Personality in Nature, Society, and Culture*. New York, University Press.
- Nadel, L. (1990). *Varieties of spatial cognition: psychobiological considerations*. In A. Diamond (Ed.) *The Development and Neural Bases of Higher Cognitive Functions*, New York Academy of Sciences.
- Newcombe, N., Bandura, M. & Taylor, D. (1983). Sex differences in spatial ability and spatial activities. *Sex Roles*, 9, 377–386.
- Newhouse, P. A., Newhouse, C. D., Astur, R. (2007). Gender Differences in Visual-Spatial Learning Using a Virtual Water Maze in Pre-Pubertal Children. *Behavioural Brain Research*, 183, 1–7.
- Nori, R., Grandicelli, S. & Giusberti, F. (2009). Individual differences in visuo-spatial working memory and real-world wayfinding. *Swiss Journal of Psychology*, 687–16.
- Nyborg, H. (1983). Spatial ability in men and women: Review and new theory. *Advances in Behavior Research and Therapy*, 5, 89–140.
- O’Laughlin, E. M. & Brubaker, B. S. (1998). Use of landmarks in cognitive mapping: gender differ. in self report versus performance. *Personality and Individual Differences*, 24, 595–601.
- Oliver, M. B. & Hyde, J. S. (1993). Gender differences in sexuality: A meta-analysis. *Psychological Bulletin*, 114, 29–51.
- Overman, W. H., Pate, B. J., Moore, K. & Peuster, A. (1996). Ontogeny of place learning in children as measured in the radial arm maze, Morris search task, and open field task. *Behavioral Neuroscience*, 10, 1205–1228.
- Picucci, L., Bosco, A. (2006). “Two cues are not better than one” the integration of geometric and featural information in the reorientation paradigm. *Cognitive Processing*, 7, 82–85.
- Postma, A. & De Haan, E. H. F. What was where? Memory for object locations. *The Quarterly Journal of Experimental Psychology*, 7, 178–199.
- Postma, A., Izendoorn, R. & De Haan, E. F. H. (1996). Sex differences in object location memory. *Brain and Cognition*, 36, 334–45.
- Postma, A., Jager, G., Kessels, R. P. C., Koppeschaar, H. P. F. & van Honk, J. (2004). Sex differences for selective forms of spatial memory. *Brain and Cognition*, 54, 24–34.
- Quaiser-Pohl, C. & Lehmann, W. (2002). Girls spatial abilities: charting the contributions of experiences and attitudes in different academic groups. *British Journal of Educational Psychology*, 72, 245–260.

- Rahman, Q., Abrahams, S., Jussab, F. (2005). Sex differences in a human analogue of the Radial Arm Maze: The "17 Box Maze Test". *Brain and Cognition*, 58, 312-317.
- Ratliff, K. R., Newcombe, N. S. (2008). Is language necessary for human spatial reorientation? Reconsidering evidence from dual task paradigms. *Cognitive Psychology*, 56, 142-163.
- Rohner, R. F. (1976). Sex differences in aggression: Phylogenetic and enculturation perspectives. *Sex Roles*, 3, 118-119.
- Rosenthal, R. (1979). The "file drawer problem" and tolerance for null results. *Psychological Bulletin*, 86, 638-641.
- Rowe, G., Turcotte, J. & Hasher, L. (2004). *The effects of age and gender on visuo-spatial working memory*. Paper presented at the 10th Cognitive Aging Conference, Atlanta, GA.
- Rybash, J. M. & Hoyer, W. J. (1992). Hemispheric specialization for categorical and coordinate spatial representations: a reappraisal. *Memory and Cognition*, 20, 271-649.
- Sadeghian, P., Kantardzic, M., Lozitskiy, O. & Sheta, W., (2005). Route recommendations: navigation assistance in complex virtual environments. *Proceedings of the Conference on Computers and their Applications*, New Orleans, LA, 220-225.
- Salthouse, T. A. (2000). Aging and measures of processing speed. *Biological Psychology*, 54, 35-54.
- Salthouse, T. A. & Siedlecki, K. L. (2007). Efficiency of route selection as a function of adult age. *Brain and Cognition*, 63, 279-286.
- Salzman, C. (2008). Pharmacologic treatment of disturbed sleep in the elderly. *Harvard Review of Psychiatry*, 16, 271-278.
- Sandstrom, N. J., Kaufman, J. & Huettel, S. A. (1998). Males and females use different distal cues in a virtual environment navigation task. *Cognitive Brain Research*, 6, 351-360.
- Saucier, D. M., Green, S. M., Leason, J., MacFadden, A., Bell, S. & Elias, L. J. (2002). Are sex differences in navigation caused by sexually dimorphic strategies or by differences in the ability to use the strategies? *Behavioral Neuroscience*, 116, 403-410.
- Schmitz, S. (1997). Gender-related strategies in environmental development: Effects of anxiety on wayfinding in and representation of a three -dimensional maze . *Journal of Environmental Psychology*, 17, 215- 228.
- Schmitzer-Torbert, N. C. (2007). Place- and response-learning in human virtual navigation: Behavioral measures and gender differences. *Behavioral Neuroscience*, 121, 277-290.
- Sherman, J. (1978). *Sex-related cognitive differences*. Springfield, IL: Charles C. Thomas.
- Siegel, A. W. & White, S. H. (1975). The development of spatial representation of large scale environments. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 10, pp. 10- 55). New York: Academic Press.
- Smythe, P. & Annett, M. (2006). Phonology and handedness in primary school: Predictions of the right shift theory. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 47, 205-212.
- Srinivasan, M. V., Zang, S., Bidwell, N. (1997). Visually mediated odometry in honeybees. *Journal of Experimental Biology*, 200, 2513-2522.
- Tlauka, M. (2006) Orientation dependent mental representations following real-world navigation. *Scandinavian Journal of Psychology*, 47, 171-176.
- Tolman, E. (1948). Cognitive maps in rats and men. *Psychological Review*, 55, 189-208.

- Vecchi, T. & Girelli, L. (1998). Gender differences in visuo-spatial processing: the importance of distinguishing between passive storage and active manipulation. *Acta Psychologica*, 99, 1–16.
- Vlachos, F., Andreou, G., Andreou, E. (2003) Biological and environmental influences in visuospatial abilities. *Learning and Individual Differences*, 13, 339–347.
- Voyer, D., Nolan, C. & Voyer, S. (2000). The relation between experience and spatial performance in men and women. *Sex Roles*, 43, 891–915.
- Voyer, D., Postma, A., Brake, B. & Imperato-McGinley, J. (2007). Gender differences in object location memory: A meta-analysis. *Psychonomic Bulletin & Review*, 14, 23–38.
- Voyer, D., Voyer, S. & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, 117, 250–270.
- Waller, D. (2005) The WALKABOUT: using virtual environments to assess large-scale spatial abilities. *Computation and Human Behaviour*, 21, 243–345.
- Waller, D., Knapp, D. & Hunt, E. (2001). Spatial representations of virtual mazes: the role of visual fidelity and individual differences. *Human Factor*, 43, 147–158.
- Waller, D., Montello, D. R., Richardson, A. E. & Hegarty, M. (2002). Orientation specificity and spatial updating of memories for layouts. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 28, 1051–1063.
- Wang, R.F. & Spelke, E. (2000). Updating egocentric representation in human navigation. *Cognition*, 77, 215–250.
- Warren, S. G. & Juraska J. M. (2000). Sex differences and estropausal effects on water maze performance in aged rats. *Neurobiology of Learning and Memory*, 74, 229–240.
- Williams, C. L., Barnett, A. M. & Meck, W. H. (1990). Organizational effects of early gonad secretions on sexual differentiation in spatial memory. *Behavioral Neuroscience*, 104, 84–97.
- Wolf, O.T. & Kirschbaum, C. (2002). Endogenous estradiol and testosterone levels are associated with cognitive performance in older women and men. *Hormones and Behaviour*, 41, 259–266.
- Yaffe, K., Lui, L.Y., Zmuda, J., Cauley, J. (2002). Sex hormones and cognitive function in older men. *Journal of American Geriatric Society*, 50, 707– 712.
- Yaski, O. & Eilam, D. (2007). The impact of landmark properties in shaping exploration and navigation. *Animal Cognition*, 10, 415–428.
- Yaski, O. & Eilam, D. (2008). How do global and local geometries shape exploratory behavior in rats? *Behavioural Brain Research*, 187, 334–342.

Chapter 5

PRETRIAL PUBLICITY AFFECTS JUROR DECISION MAKING AND MEMORY

Christine L. Ruva

University of South Florida, FL, US

ABSTRACT

Pretrial publicity (PTP) has been found to have a biasing effect on jury decision making. This chapter explores how research and theory in cognitive psychology has been used to examine the mechanisms responsible for PTP's biasing effects on jury decisions. This research can assist the courts in finding effective remedies for PTP bias. The chapter explores how exposure to PTP is similar to exposure to misinformation in the reversed suggestibility paradigm and that memory for the trial can be affected by misinformation (PTP) presented before the trial (Lindsay & Johnson, 1989; Rantzen & Markham, 1992). The chapter will also review research and theory examining whether memory errors (e.g., source misattributions) and biases of individual jurors are likely to be corrected by jury members during deliberations. A review of relevant literature is followed by the presentation of two research studies. The first study explores whether deliberation reduces the biasing effects of PTP by comparing group (jury) and individual (juror) decisions using the nominal group method.

This study also explores whether jurors who are exposed to PTP are likely to misattribute information presented only in the PTP to the trial. The second study explores the effects of both negative (anti-defendant) and positive (pro-defendant) PTP on juror decision making. Both studies suggest that even if jurors are instructed not to use information contained in the PTP to make decisions about guilt, they may be unable or unwilling to do so because of source memory errors and their perceptions of the defendant and trial attorneys.

This research also suggests that jury deliberations can increase (polarize) juror bias and therefore, cannot be counted on to remedy the effect of PTP on jury decision making.

INTRODUCTION

The prevalence of pretrial publicity (PTP) in today's media-rich culture is problematic for the courts given their duty to protect a defendant's Sixth Amendment right to a "speedy and public trial, by an impartial jury" (United States Constitution) while protecting citizens' First Amendment rights to free speech. Research has demonstrated that PTP can bias juror decision making by impeding jurors' ability to reach a verdict based solely on evidence presented at trial (Carlson & Russo, 2001; Dexter, Cutler, & Moran, 1992; Hope, Memon, & McGeorge, 2004; Kerr, Niedermeier, & Kaplan, 1999; Kovera, 2002; Kramer, Kerr, & Carroll, 1990; Ogloff & Vidmar, 1994; Otto, Penrod, & Dexter, 1994; Ruva & McEvoy, 2008; Ruva, McEvoy, & Bryant, 2007; Steblay, Besirevic, Fulero, & Jimenez-Lorente, 1999). A number of lower courts' decisions have resulted in reversals due to failure of these courts to protect defendants' rights to a fair trial (e.g., *Irvin v. Dowd*, 1961 and *Sheppard v. Maxwell*, 1966; see Davis, 1986, Imrich, Mullin, & Linz, 1995 and Posey & Wrightsman, 2005 for reviews). The courts have attempted to remedy the problem of juror bias associated with PTP exposure in several ways (e.g., judicial instructions, voir dire, continuance, and change of venue; see Steblay et al., 1999 for review). However, these remedies are often ineffective, unavailable, or not easily obtained by a defendant (Deitz & Sissman, 1984; Dexter et al., 1992; Kramer et al., 1990; Moran & Cutler, 1991).

The failure of the courts to find effective remedies for PTP bias may be due to an inadequate understanding by the courts and social scientist as to how PTP imparts its biasing effects on juror decision making (Moran & Cutler, 1991; Ruva et al., 2007; Studebaker & Penrod, 1997). This chapter explores how research and theory in cognitive psychology have been used to examine the mechanisms responsible for PTP's biasing effects on jury decisions. This research can assist the courts in making educated decisions on the types of remedies that may be effective in combating PTP effects.

REVERSE SUGGESTIBILITY PARADIGM AND SOURCE MEMORY THEORY

PTP may impart its biasing effects on jury decision making by affecting juror memory for trial evidence. Research on the misinformation effect (Loftus & Palmer, 1974) and source memory (Johnson, Hashtroudi, & Lindsay, 1993) suggest that jurors may have a difficult time distinguishing between information that they receive before trial in the form of PTP and evidence presented at trial. Research has consistently demonstrated that people's memory for an event can be significantly influenced by misinformation presented after an event (Loftus & Palmer, 1974; see Ayers & Reder, 1998 for review). Research in this area is typically conducted using Loftus and Palmer's (1974) paradigm in which participants are first shown the to-be-remembered event which is followed by the presentation of misinformation. Participants are then given a recognition test asking them to indicate which items were presented in the original event. The consistent finding of this research is that the misinformed participants are more likely to attribute post-event misinformation to the original event than are control participants who were not exposed to the misinformation.

In the reversed suggestibility paradigm the order of presentation of the misinformation and the target event is reversed with the misinformation being presented before the target event. Research using this paradigm has shown that memory performance is also affected by misinformation presented before the to-be-remembered event (Lindsay & Johnson, 1989; Rantzen & Markham, 1992). The reverse suggestibility paradigm creates an experimental situation that is similar to the real world situation of juror exposure to PTP (misinformation) and the trial (to-be-remembered event). Jurors may believe that the PTP they were exposed to was part of the trial event because they are unable to distinguish between these two sources of information. Such errors are called source memory errors (Johnson et al., 1993; Lindsay, 1994; Weingardt, Toland, & Loftus, 1994). Source memory (SM) errors occur because memory performance for event information is generally better than memory for source information (Kelly, Carroll, & Mazzoni, 2002).

Research has demonstrated that source memory errors increase as the delay between encoding and retrieval of a fact increases (Frost, Ingraham, & Wilson, 2002). A delay between exposure to information (e.g., PTP) and retrieval of that information (during jury deliberations) could lead to a type of sleeper effect (Davis, 1986; Honess, Charman, & Levi, 2003) in which a low credibility or unreliable source (PTP) is not remembered and the information is attributed to a credible or reliable source (the trial). These types of memory errors suggest that some judicial remedies may be ineffective in combating PTP bias. For example, judicial instructions admonishing jurors not to use PTP may be ineffective because jurors cannot distinguish between the two sources of case information (PTP and trial evidence). This is problematic because the courts generally assume that juries are able to abide by judicial instructions admonishing them not to discuss the PTP during jury deliberations (Stebly, Hosch, Culhane, & McWethy, 2006; Studebaker & Penrod, 1997). Research investigating individual jurors suggests that judicial instructions have little if any affect on PTP bias (Stebly et al., 2006) and source memory errors may be one reason for their ineffectiveness.

VALENCE OF THE PTP AND SOURCE MEMORY

Although in most cases PTP is predominately negative or anti-defendant (Imrich et al., 1995), some recent high profile cases have produced large amounts of positive or pro-defendant PTP. These cases usually involve very wealthy defendants who are well known to the public prior to being charged with a crime (e.g., Michael Jackson, Martha Stewart, and Kobe Bryant; Ruva & McEvoy, 2008). Almost all of the PTP literature has focused on the effects of negative PTP on juror bias. Therefore, little is known about the effects of positive PTP on juror bias (Ruva & McEvoy 2008). In this chapter we explore the effects of both positive and negative PTP on juror bias and whether the valence of PTP affects jurors' source memory accuracy. Research on autobiographical memory suggests that people have better memory for positive events than for negative ones (Pollyanna principle: Christianson & Safer, 1996; Walker, Skowronski, & Thompson, 2003). The majority of laboratory research suggests that people are more likely to recall emotional stimuli than neutral stimuli, but most of this research only included negatively valenced emotional stimuli. Research including both negatively and positively valenced information has mixed results, with some researchers

finding better recall of negative stimuli (Kern, Libkuman, Otani, & Holmes, 2005), others findings better recall for positive stimuli (Lang, Dhillon, & Dong, 1995), and others finding no differences between negative and positive stimuli, but both better recalled than neutral stimuli (Doerksen & Shimamura, 2001).

Only a few studies have explored how emotional valence of material affects source memory. In general, source memory is more accurate for emotional stimuli (Kensinger & Corkin, 2003), but in the few cases when negatively and positively valenced items were included, source memory was equivalent for the two types of emotional stimuli (D'Argembeau & Van der Linden, 2004; Doerksen & Shimamura, 2001).

IMPRESSION FORMATION AND VALENCE OF THE PTP

Pretrial publicity may also influence jurors' verdicts by causing jurors to form either negative (in the case of negative or anti-defendant PTP) or favorable (in the case of positive or pro-defendant PTP) impressions of the defendant. These impressions then may influence jurors' interpretations of trial evidence and hence their verdicts (Otto et al., 1994). Research on person perception has found that people pay more attention to negative information than positive information (Fiske, 1980; Meffert, Chung, & Joiner, 2006; Rozin & Royzman, 2001), which is referred to as the *negativity bias*. The negativity bias suggests that positive PTP might not have as strong of an effect on defendant credibility and juror verdicts as negative PTP. Direct testing of this hypothesis is needed and Experiment 2 presented in this chapter was designed to test it.

GROUP DECISION MAKING

Research exploring the mechanisms responsible for the biasing effects of PTP has primarily focused on juror decision making and has not included jury deliberations. Although it is important to explore whether some mechanism mediates the effect of PTP on juror bias at the individual or juror level, ultimately researchers must investigate whether these effects are attenuated or accentuated by jury deliberations.

Groups Catch Errors

Although individual jurors may succumb to the memory errors and biases, courts have assumed that groups (e.g., juries) are especially good at catching memory errors and balancing out the biases of their members (Bourgeois, Horowitz, Fosterlee, & Graphe, 1995; Davis, 1992; Pritchard & Keenan, 2002). As Davis, Spitzer, Nagao, and Stasser (1978) point out:

Jurors may deviate systematically from the true value by virtue of imperfections in perception, memory, recall, reasoning and many other features of the information-processing apparatus of humans. However, these are irreducible and the whole point of using a group

rather than a single individual is that fluctuations in cognition may be muted in the former (p. 36).

This conclusion implies, for example, that if one juror mistakenly misattributes the source of PTP to be at trial and then tries to use this information during jury deliberations as evidence for or against guilt, at least one other group member will catch and correct this error. Thus, collaborating groups are thought to be less susceptible than individuals to source misattributions and other types of memory errors. The supposedly superior “error catching” ability of collaborating groups is one reason why our court system relies on groups of people (juries) to make decisions about guilt (Bourgeois et al., 1995; Davis et al., 1978).

A number of studies have found that groups produce fewer memory errors (e.g., false memories, inferential errors, and confusional errors) than do individuals (Clark, Stephenson, & Rutter, 1986; Clark, Stephenson, & Kinveton, 1990; Hartwick, Sheppard, & Davis, 1982; Hinz, 1990; Stephenson, Abrams, Wagner, & Wade, 1986; Vollrath, Sheppard, & Hinsz, 1989). However in other studies, collaborating groups were found to be more susceptible to memory errors than were individuals or nominal groups (Basden, Basden, Bryner, & Thomas 1997; Basden, Basden, Thomas, & Souphasith, 1998; Sheppard, 1980, as cited in Clark et al., 1990; Vollrath et al., 1989). These inconsistent findings may be due to methodological differences, which make comparisons among studies difficult. Also, the majority of this research has required group consensus on the accuracy of an item before it was recorded, making comparisons between collaborative and nominal groups less meaningful. Findings from research in which consensus on individual memory items are required are also difficult to apply to jury decision making because jurors must come to a consensus on their final decision (guilty vs. not guilty), but not on each fact or argument presented during deliberations.

Very little research has been conducted to explore the effect of collaboration on memory errors utilizing a method that does not require consensus and that uses the nominal group method. The existing research of this type indicates that collaboration, rather than reducing memory errors, may actually increase them. For example, Basden and colleagues, employing Deese, Roediger, and McDermott’s (1995) paradigm, have demonstrated that collaborating groups produce as many or more false memories than do nominal groups (Basden et al., 1997, 1998). Basden et al. (1997) attributed the collaborative groups’ higher number of false recalls to members feeling some obligation to contribute and therefore lowering their response thresholds.

Collaboration has been found to increase people’s confidence in both their accurate and inaccurate memory judgments (Clark, et al., 1990; Stephenson & Wagner, 1989; Stephenson, et al., 1986). This propensity for collaboration to increase people’s confidence in their inaccurate memory judgments has been labeled the “misplaced overconfidence effect” (Stephenson & Wagner, 1989; Stephenson, et al., 1986). Group members’ elevated confidence in inaccurate memories suggests that collaboration may increase memory errors

Groups Balance Out Biases

Some research supports the view that groups balance out the biases of their individual members, in that juries demonstrate less bias (e.g., bias due to PTP, inadmissible evidence, or

dispositional bias effects) than individual jurors (Kaplan & Miller, 1978; London & Nunez, 2000; Wright & Wells, 1985). Other studies have found little or no difference in predeliberation versus post-deliberation biases (Davis et. al., 1978; Hans & Doob, 1976). Whereas, other studies have found juries to be more biased (e.g., group polarization effect) than individual jurors (Alderton & Frey, 1983 and 1986; Kramer et. al., 1990).

One explanation for these inconsistent findings derives from Kalven and Zeisel's (1966) liberation hypothesis which states that juror bias is likely to be most influential in ambiguous cases. In ambiguous cases "the closeness of the evidence makes it possible for the jury to respond to sentiment by liberating it from the discipline of the evidence" (Kalven & Zeisel, 1966, p. 165). That is, as ambiguity increases, the effect of non-legal or extra-evidentiary factors on verdicts also increases, as well as the use of heuristic (rather than in-depth) processing (Boyll, 1991; Petty & Wegner, 1998). Support for the liberation hypothesis was demonstrated by Kerr et al.'s (1999) finding that the effect of jury deliberation on extralegal biases interacts with trial strength (or ambiguity). That is, jury deliberation in moderate (ambiguous) trials resulted in group polarization effects (increased bias), but either decreased juror bias or had no effect on juror bias in strong trials. Kerr et al.'s findings also suggest that studies which examine mock juror judgments in the absence of group deliberation may underestimate bias when the case is ambiguous and overestimate bias when the case is imbalanced (favoring either the prosecution or defense).

Of course, case strength (or trial ambiguity) is not the only factor responsible for the inconsistent effects of deliberation on juror bias. Other factors noted in the literature include variation of methods, type of bias examined (e.g., PTP, inadmissible evidence, or dispositional bias), and strength of predeliberation bias (Davis, 1973; Kerr et al., 1999). This chapter focuses on case strength (or trial ambiguity) because research shows that only a small percentage of cases go to trial (less than 2%, Boyll, 1991) and those cases that do make it to trial are often ambiguous as to guilt (evidentially close; Boyll, 1991). Therefore, the use of ambiguous trials in PTP research should increase the ecological validity of this research. In contrast, using imbalanced trials may lead to underestimating the effect of PTP on jury decisions and overestimating the ability of juries to reduce or eliminate these biases.

In summary, it is important for social scientists and the courts to understand how PTP imparts its biasing effects on juror decision making for number of reasons. First, the prevalence of PTP in today's media rich culture makes it difficult to find jurors that have not been exposed to PTP (Studebaker & Penrod, 1997), at least in high-profile cases. Therefore, it is important for the courts to understand how PTP influences juror decisions so that they can impose effective remedies to reduce or eliminate PTP bias. Second, the courts believe that judicial instructions are effective in combating PTP bias (Steblay et al., 2006). Unfortunately, judicial instructions admonishing jurors to disregard PTP will not be effective if jurors cannot distinguish between information presented in the PTP and that presented at trial (source memory errors). The experiments in this chapter explore jurors' ability to accurately identify the source of their case knowledge. Finally, the courts believe that although individual jurors may succumb to memory errors and biases, juries will correct memory errors and balance out biases of their members. Unfortunately, there is not a lot of support for this belief in the social science literature. Instead, groups often polarize the biases held by the majority of their members. The ability of groups to balance out biases and reduce memory errors is explored in Experiment 1.

EXPERIMENT 1

Overview of Experiment

Experiment 1 consisted of two phases that were approximately four days apart. During the first phase of the experiment mock-juror participants read negative PTP or unrelated crime stories. During phase 2 the mock-jurors viewed a videotaped murder trial. Then half of the jurors deliberated and came to a group decision about guilt (collaborating jurors) and the other half made verdict decisions on their own (nominal jurors). After rendering verdicts all of the participants completed the remaining experimental tasks on their own which included a source memory test and a credibility questionnaire. The source memory tests included information that appeared only in the trial, in PTP, in unrelated news articles, or in neither trial nor the PTP (new information).

Hypotheses

Jurors exposed to negative PTP were expected to be more likely than nonexposed jurors to find the defendant guilty and to misattribute information presented only in the PTP to the trial (critical source memory error). The negative PTP exposed jurors were also expected to rate the defendant as being less credible than non-exposed jurors.

These PTP exposure effects were expected to interact with juror collaboration on the post-deliberation measures of guilt and on credibility ratings. Collaborating jurors who were exposed to PTP were expected to be significantly more likely, after deliberation, to render guilty verdicts, give higher guilt ratings, and perceive the defendant as being less credible than all other groups. Group discussion was expected to polarize PTP exposed jurors prediscussion preferences associated with viewing the defendant as guilty (Alderton & Frey, 1983, 1986; Davis, 1992; Kerr et al., 1999; Kramer et al., 1990; Seibold & Meyers, 1986).

Collaboration was also expected to affect jurors' confidence in their source memory judgments, with collaborating jurors indicating higher levels of confidence in both their accurate and inaccurate (misplaced overconfidence effect) source memory judgments than nominal jurors. Due to the inconsistent findings in the collaborative memory research, no prediction was made in regards to collaboration's effect on critical source memory errors.

Method

Participants

The participants consisted of 558 jury-eligible students from a southeastern university who received extra-course credit for their participation. One-hundred and twenty eight were men and 430 were women and they ranged in age from 18 to 52 years ($M = 20.6$ years). There were 138 participants in both of the collaborating groups, 140 in the nominal exposed groups and 142 in the nominal nonexposed groups. Participants were randomly assigned to one of the collaboration conditions (collaborative vs. nominal) at the beginning of phase 2.

Design

A 2 (PTP: exposed vs. nonexposed) x 2 (collaboration: collaborating vs. nominal) between subjects hierarchical design was utilized for this experiment. There were 25 groups (juries) per condition. The exposed jurors read negative PTP and the nonexposed jurors read unrelated crime articles. The nominal groups were randomly generated after data collection was completed and consisted of 5 to 6 individuals who worked alone on all experimental tasks. The collaborating groups consisted of 4 to 6 people who deliberated as a jury and made a group decision regarding guilt of the defendant. Of our 50 groups of collaborating jurors, 68% consisted of 6 jurors, 18% consisted of 5 jurors, and 14% consisted of 4 jurors. Many researchers employ mock juries that contain fewer than 12 people because using 12-person juries would make most mock jury research prohibitive. Research examining the effects of jury size on outcomes suggests that 6-person juries are more variable in their outcomes, have shorter deliberations, and are less likely to be hung than 12-person juries, but has established little else (Devine, Clayton, Dunford, Searing, & Pryce, 2000; Saks and Marti, 1997).

Stimuli

Trial. The stimulus trial consisted of a videotaped murder trial (*NJ v Bias*) of a man who was accused of murdering his wife and was edited to run approximately 30 minutes. Pilot work and previous research (Hope et al., 2004; Pritchard & Keenan, 1999, 2002) indicated that the trial was ambiguous as to guilt and was perceived as being realistic and believable.

Pretrial publicity. All participants read news articles about crimes that were taken from a web-based archive for the *Morning Call* newspaper. Participants in the PTP exposed conditions read modified PTP that had surrounded the *NJ v Bias* trial. These news stories contained general information about the case (e.g., victim, when and where the crime took place, description of the crime) as well as information that was not presented at trial and that could have a biasing effect on juror verdicts (see Appendix A for examples of PTP and trial facts).

Participants in the non-exposed PTP conditions read actual news articles involving a woman who was accused of embezzling child support funds. These articles were similar in composition to the news articles in the exposed condition (i.e., both packets contained 9 separate news articles of approximately the same length and consisted of 10 pages of text).

Measures

Verdicts and guilt ratings. The participants were asked for their verdicts (not guilty = 1, hung = 2, or guilty = 3) and their guilt ratings which is a score that combines a verdict and a confidence rating into a single score (1 = I am certain he is not guilty to 7 = I am certain he is guilty).

Source monitoring test. The source memory test required participants to indicate whether a particular statement appeared in the experiment either as part of the trial or in one of the articles they read, and if so, the source of the item (i.e., trial, articles, or both the trial and articles). This test contained information presented only in the trial, information provided only in the PTP, information provided only in the unrelated articles, and information not provided in either the PTP or the trial. Participants were also required to indicate how confident they were in each of their source judgments using a seven-point Likert scale with 1

indicating that they were not at all confident and 7 indicating they were extremely/completely confident.

Credibility and attorney ratings. The credibility of the defendant was assessed by asking participants to rate the defendant, using a seven-point Likert scale, on a number of characteristics relevant to credibility (e.g., memory accuracy, confidence, consistency of testimony, bias/objectivity, and honesty; see Ruva & Bryant, 2004 for complete scale). Participants also rated the prosecuting and defense attorneys on 3 characteristics (overall ability, likableness, how well they each performed their respective roles by either proving guilt or demonstrating reasonable doubt).

Procedure

First phase. During phase 1, the participants were told that the study had two-parts and examined the stability of emotional reactions to different types of information. Therefore, they needed to come back the following week for the second part of the experiment. This cover story was provided so that the participants would not know they were part of an experiment involving jury research.¹ Participants then received packets containing either PTP or unrelated news articles and were asked to read all of the articles thoughtfully. They were then given 15 minutes to write down as much information as they could remember from the news articles. After recall was completed they were asked to indicate their emotional response to reading each piece of information.

Second phase. Approximately four days ($M = 4.02$, $SD = 0.80$, range = 4 to 7 days) after exposure to the articles, participants viewed the videotaped trial. Prior to viewing the trial jurors were informed that during the first phase of the study they might have read news articles related to the trial that they were about to view. They were instructed not to use any of the information from these articles when making verdict decisions. For this decision they must only use the evidence presented during the trial. The videotaped trial was then presented. Immediately following the viewing of the trial, each juror provided a verdict and guilt rating. Then those in the nominal group were moved to a different room from that of the collaborating group.

The collaborating jurors were given 30 minutes to deliberate and come to a group decision. They were informed that if such a verdict was not reached within 30 minutes the jury would be considered hung, resulting in a mistrial. They were informed that they would receive a warning five minutes prior to the end of the deliberation period and at that time they should finish deliberations and decide on a verdict. The experimenter then left the room and did not return until it was time to give the 5-minute warning. If the jury had not reached a unanimous decision at that time they were instructed to try their best to do so within the next 5 minutes.

The nominal jurors were asked to individually recall in writing as many trial facts as they could. They were given 15 minutes to complete this task. They were then asked to indicate, in the space provided on the recall sheet, which trial facts had the greatest influence on their decision and why. They were given 10 minutes to complete this task. The nominal jurors then individually completed a verdict form. This verdict form was the same as the one completed

¹ A debriefing questionnaire was administered at the end of phase 2 in order to assess whether the participants believed the cover story from phase 1 of the experiment. The majority of both PTP exposed (83%) and nonexposed jurors (84%) indicated that they did in fact believe the cover story, $\chi^2(2, N = 558) = .21, p = .65$.

by collaborating jurors except that it did not provide the verdict option of hung. The purpose of the recall task was two-fold: (1) to keep the time between trial and source monitoring test equivalent across conditions and (2) to allow nominal jurors to engage in an activity that resembled the process that a juror might engage in if that juror had participated in jury deliberations.

Once the verdict forms were collected, jurors in both the collaborating and nominal conditions each individually completed the SM test and indicated their confidence in each answer (see Appendix A). Participants were then asked individually to report verdicts and guilt ratings one final time as well as their ratings of the defendant's credibility.

Results

The guilt measures, which included verdicts and guilt ratings, were completed by the jurors three times: (1) just prior to deliberations (predeliberation measures), (2) just after deliberations (collaborating jurors) or recalls (nominal jurors; post-deliberation measures), and (3) just after the source memory test all jurors provided individual verdicts (post-source memory measures).

For each guilt measure a 2 (PTP exposure: exposed vs. nonexposed) $\times$ 2 (collaboration: collaborating vs. nominal) between-subjects hierarchical ANOVA² was performed. A hierarchical nested design with participants nested within groups and groups nested within PTP exposure and collaboration conditions was employed because half of the mock-jurors participated in group deliberations.

The nested error term³ was used for all of the *F*-tests except for those involving the predeliberation guilt measures and the analyses using the nested error term the level of analysis for the nominal juries is the group mean. Effect sizes for ANOVAs are reported as Cohen's (1988) *d*.

Predeliberation Guilt Measures

As predicted, jurors in the exposed PTP conditions were significantly more likely to vote guilty than jurors in the nonexposed conditions (see Table 1), $F(1, 458) = 54.89$, $MSE = .86$, $p < .01$, $d = .63$. Also as predicted, the jurors in the exposed PTP conditions gave significantly higher guilt ratings than did jurors in the nonexposed conditions (see Table 1), $F(1, 458) = 74.48$, $MSE = 2.51$, $p < .01$, $d = .74$. There were no significant main or interactive effects of collaboration on any of the predeliberation guilt measures (see top panel of Table 2 for frequency of predeliberation verdicts by PTP and collaboration conditions).

² Hierarchical ANOVAs allowed us to test for significant effects of groups nested within PTP exposure and collaboration conditions and then use the more appropriate error term (nested error term) if this effect was significant. Chi square does not allow for these types of analyses.

Table 1. Means for the Guilt Measures for Experiment 1

Predeliberation	Post-deliberation	Post-Source Monitoring							
Exposed	Nonexposed	Mean	Exposed	Nonexposed	Mean	Exposed	Nonexposed	Mean	
Verdicts ^b									
Collaborating	2.46 (0.89) ^a	1.83 (0.99)	2.15 (0.99)	2.22 (0.84)	1.72 (0.72)	1.97 (0.82)	2.25 (0.97)	1.67 (0.94)	1.95 (1.00)
Nominal	2.30 (0.96)	1.74 (0.97)	2.02 (1.00)	2.27 (0.97)	1.71 (0.96)	1.99 (1.00)	2.27 (0.97)	1.71 (0.96)	1.99 (1.00)
Mean	2.38 (0.93)	1.78 (0.98)	2.25 (0.90)	1.72 (0.85)	2.25 (0.97)	1.69 (0.95)			
Guilt Ratings ^c									
Collaborating	5.29 (1.65)	4.08 (1.67)	4.69 (1.77)	5.63 (1.30)	3.96 (1.27)	4.79 (1.53)	5.45 (1.44)	4.04 (1.53)	4.75 (1.64)
Nominal	5.05 (1.50)	3.89 (1.61)	4.47 (1.66)	5.07 (1.61)	3.99 (1.71)	4.54 (1.74)	5.09 (1.60)	3.99 (1.68)	4.54 (1.73)
Mean	5.17 (1.58)	3.98 (1.64)	5.34 (1.49)	3.97 (1.50)	5.27 (1.53)	4.01 (1.61)			

a. Standard deviations appear in parentheses.

b. The following scale was used to code verdicts: 1 = not guilty, 2 = hung, 3 = guilty. The hung option was only available for jurors in the collaborative conditions when deciding verdict 2.

c. The following scale was used for guilt ratings: 1 = high confidence not guilty, 4 = unsure whether defendant is guilty or not guilty, 7 = high confidence guilty.

Table 2. Frequency Counts and Percentages for Verdicts for Experiment 1

Condition	Not Guilty	Hung	Guilty	Total
Predeliberation Verdicts				
Collaboration x PTP				
Collaborating Exposed	37 (27%) ^a	NA ^b	101 (73%)	138
Collaborating Nonexposed	81 (59%)	NA	57 (41%)	138
Nominal Exposed	50 (35%)	NA	92 (65 %)	142
Nominal Nonexposed	88 (63%)	NA	52 (37%)	140
Total	256 (46%)	NA	302 (54%)	558 (100%)
Post-deliberation Verdicts				
Collaboration x PTP				
Collaborating Exposed	36 (26%)	35 (25%)	67 (49%)	138
Collaborating Nonexposed	60 (43%)	56 (41%)	22 (16%)	138
Nominal Exposed	52 (37%)	NA	90 (63%)	142
Nominal Nonexposed	90 (64%)	NA	50 (36%)	140
Total	238 (43%)	91 (16%)	229 (41%)	558 (100%)
Collaboration x PTP				
Collaborating Exposed	52 (38%)	NA	86 (62%)	138
Collaborating Nonexposed	92 (67%)	NA	46 (33%)	138
Nominal Exposed	52 (37%)	NA	90 (63%)	142
Nominal Nonexposed	90 (64%)	NA	50 (36%)	140
Total	286 (51%)	NA	272 (49%)	558 (100%)

^a Row percentages appear in parentheses beside their respective means.

^b Only collaborating jurors could render a hung verdict (null verdict) during the group decision.

Post-deliberation and Post- Source Memory Guilt Measures

Because the results for the post-deliberation and post-source monitoring measures were similar these results are presented together. The post-deliberation results are listed first for each analysis. As predicted, jurors exposed to PTP were significantly more likely than non-exposed jurors to vote guilty, $F_s(1, 96) = 15.49$ and 20.48 , $MSE_s = 2.35$ and 2.03 , $ps < .01$, $ds = .60$ and $.57$ and give higher guilt ratings, $F_s(1, 96) = 39.57$ and 41.84 , $MSE_s = 6.42$ and 5.04 , $ps < .01$, $ds = .75$ and $.80$ (see Table 1). There were no significant main or interactive effects of collaboration on any of the post-deliberation or post-source monitoring guilt measures (see Tables 1 and 2).

In order to examine further whether jury deliberation had an effect on the guilt measures, three-way (PTP exposure, collaboration, and time of test) mixed-design hierarchical ANOVAs were performed with the predeliberation and post-source monitoring data with verdicts and guilt ratings as the within-subjects variable. On the verdict measure, there was a significant effect of time of test and a significant interaction between time of test and collaboration, $F(1, 96) = 11.86$ and 6.63 , $MSE = 0.285$, respectively. Overall, jurors were less likely to find the defendant guilty on the post-source monitoring measures than on the predeliberation measures (see Tables 1 and 2), but this effect was only apparent for the jurors

in the collaborating conditions. This finding suggests a leniency shift in which deliberation may heighten awareness of the defendant protection norm and highlight the reasonable doubt standard that acquitting the guilty is less serious an error than convicting the innocent (Kerr, 1993). Regardless of time of test, PTP had a significant effect on verdicts with jurors in the exposed conditions being significantly more likely to find the defendant guilty than jurors in the nonexposed conditions, $F(1, 96) = 30.65$, $MSE = 2.89$, $p < .01$. The interaction between time of test and PTP exposure was not significant, $F(1, 96) = .30$, $MSE = 0.285$, $p = .51$, suggesting that PTP exposure does not contribute to the time of test effect.

Source Memory Test, Critical Source Errors

The PTP errors of interest were those in which participants misattributed information contained only in the PTP as appearing in the trial or in both the trial and the PTP (Zaragoza & Lane, 1994). The uncorrected mean proportions of source monitoring responses are shown in Table 3. These mean proportions were not analyzed, per convention. Instead, the corrected scores were used in all source memory analyses. Corrected scores were calculated as follows: the proportion of critical source monitoring errors made by each participant was calculated as an error score which was corrected by subtracting from it the proportion of new items identified as being either in the trial or in both the trial and the PTP (see Table 3). As predicted, jurors who were exposed to PTP made significantly more critical source monitoring errors ($M = .15$, $SD = .13$) than did nonexposed jurors ($M = .10$, $SD = .12$), $F(1, 96) = 17.07$, $MSE = 0.02$, $p < .01$, $d = .40$. That is, jurors exposed to PTP were significantly more likely than non-exposed jurors to attribute information presented only in the PTP to either the trial or both the trial and the PTP. Neither the main effect of collaboration nor the interaction of collaboration and PTP exposure were significant, $F_s(1, 96) = 0.49$ and 0.015 , $MSE = 0.02$, $ps > .60$), respectively.

Source Memory Test, Correct Judgments of Trial Items

There was a significant effect of PTP on correct source judgments for trial items (corrected for guessing) with jurors in the nonexposed conditions accurately identifying significantly more of the trial items as coming from the trial ($M = .75$, $SD = .17$) than did the exposed jurors ($M = .63$, $SD = .17$), $F(1, 457) = 76.56$, $MSE = 0.03$, $p < .05$, $d = .71$. There was also a small but significant main effect of collaboration, with collaborating jurors providing more accurate responses ($M = .70$, $SD = 0.16$) than nominal jurors ($M = .67$, $SD = 0.20$), $F(1, 457) = 6.36$, $MSE = 0.028$, $p < .01$, $d = .17$. The interaction was not significant, $F(1, 457) = 1.11$, $MSE = 0.028$, $p = .24$.

Confidence in Source Memory Judgments

As expected, jurors in the collaborating conditions were more confident than nominal jurors about both their correct and incorrect SM judgments for the trial items (see Table 4), $F_s(1, 96) = 5.15$ and 5.44 , $MSEs = 0.57$ and 1.65 , $p < .05$, $ds = .20$ and $.08$, respectively. PTP exposure did not have a significant effect on these confidence judgments, $F_s(1, 96) = 3.03$ and 4.75 , $MSEs = 0.57$ and 1.65 , respectively, $ps > .06$. There was no significant effect of collaboration or PTP exposure on confidence ratings for the critical SM errors, $F_s(1, 96) = 1.07$ and 1.43 , $MSE = 1.22$, respectively, $ps > .18$.

Table 3. Mean Proportions of Source Monitoring Responses as a Function of PTP Exposure and Collaboration for Experiment 1

Collaborating Exposed Jurors			
		Actual Source	
Response	Trial	Pretrial Publicity	New
Trial	.67	.04	.01
Pretrial Publicity	.05	.57	.22
Both	.15	.14	.01
New	.14	.25	.76
Collaborating Nonexposed Jurors			
		Actual Source	
Response	Trial	Pretrial Publicity	New
Trial	.79	.13	.03
Pretrial Publicity	.00	.00	.00
Both	.00	.00	.00
New	.21	.87	.97
Nominal Exposed Jurors			
		Actual Source	
Response	Trial	Pretrial Publicity	New
Trial	.63	.04	.03
Pretrial Publicity	.05	.56	.18
Both	.11	.15	.02
New	.21	.25	.77
Nominal Nonexposed Jurors			
		Actual Source	
Response	Trial	Pretrial Publicity	New
Trial	.77	.13	.03
Pretrial Publicity	.00	.00	.00
Both	.00	.00	.00
New	.22	.87	.96

Table 4. Mean Confidence Ratings for Correctly and Incorrectly Recognized Trial and Critical Source Memory Errors for Experiment 1

Condition		
Response	Collaborating	Nominal
Trial Correct	6.38 (0.59)	6.25 (0.70)
Trial Incorrect	5.56 (1.19)	5.33 (1.28)
Critical Source Errors	5.81 (0.94)	5.73 (1.06)

Note. Standard deviations are presented in parentheses following their respective means. Critical source errors include items that were incorrectly attributed to the trial or both the trial and PTP.

Credibility Measures

As predicted, the jurors exposed to PTP perceived the defendant as less credible ($M = 40.83$, $SD = 10.58$) than jurors in the nonexposed conditions ($M = 49.57$, $SD = 12.98$), $F(1, 96) = 41.48$, $MSE = 114.16$, $p < .01$, $d = .74$. There was also a significant effect of

collaboration on perceived credibility of the defendant, $F(1, 96)^3 = 8.71$, $MSE = 114.16$, $p < .01$, $d = .32$, with nominal jurors perceiving the defendant as more credible ($M = 47.13$, $SD = 12.31$) than did collaborating jurors ($M = 43.20$, $SD = 12.62$).

Mediation Analyses

One of the main purposes for this research was to explore how PTP imparts its biasing effect on jury decision making. It was hypothesized that both critical SM errors and perceived credibility of the defendant may be relevant mechanisms. In order to explore these relationships both critical SM errors and perceived credibility of the defendant, were treated as mediation variables in two mediation models of $X \rightarrow M \rightarrow Y$ (where X is PTP, Y is post-source monitoring test guilt ratings, and M is the mediating variable) (Baron & Kenny, 1986; Shrout & Bolger, 2002). As Baron and Kenny (1986) suggested, we constructed three regression equations for both models. For the model with critical SM errors the first equation related guilt ratings to PTP ($X \rightarrow Y$) and was statistically significant, $\beta = 1.25$, $t(556) = 9.44$, $p < .01$. The second related critical SM errors to PTP ($X \rightarrow M$) and was statistically significant, $\beta = -.05$, $t(556) = 4.6$, $p < .01$. The third equation related the guilt ratings to both PTP and critical SM errors and indicated that both critical SM errors and PTP were significant, $\beta = 1.28$ and 1.19 , $t(555) = 2.45$ and 8.84 , respectively, $ps < .05$. The indirect effect of PTP on the guilt ratings via the mediator (critical SM errors) was significant, Sobel test $z = 2.17$ (1982), $p < .05$. Therefore, the critical SM errors mediate the effect of PTP on guilt ratings and may be mechanisms through which PTP imparts its biasing effects.

Another mediation analysis was performed to test the model of $X \rightarrow M \rightarrow Y$ (where X is PTP, Y is post-source monitoring guilt ratings, and M is perceived credibility of the defendant) (Baron & Kenny, 1986; Shrout & Bolger, 2002). The first regression equations related guilt ratings to PTP ($X \rightarrow Y$) and was statistically significant, $\beta = 1.25$, $t(556) = 9.44$, $p < .01$. The second related perceived credibility of the defendant to PTP ($X \rightarrow M$) and was statistically significant, $\beta = -8.73$, $t(556) = -8.71$, $p < .01$. The third related the guilt ratings to both PTP and defendant's credibility and indicated that both defendant's credibility and PTP were significant, $\beta = -.09$ and $.50$, $t(555) = -20.07$ and 4.67 , respectively, $p < .01$. The indirect effect of PTP on the guilt ratings via the mediator (perceived credibility of the defendant) was significant, Sobel test $z = 2.44$ (1982). Overall, the mediation analyses suggest that the effect of PTP on guilt ratings was mediated by both the perceived credibility of the defendant and critical SM errors.

The results of Experiment 1 suggests that jurors who are exposed to negative PTP are more likely to render guilty verdicts and view the defendant as less credible than non-exposed jurors. Unfortunately, jury deliberations did not reduce PTP's biasing effect on juror verdicts. Instead, it increased juror bias with PTP exposed jurors who deliberated rating the defendant as being lower in credibility than PTP exposed jurors who did not deliberate. This finding is significant given that defendant credibility ratings were found to mediate the effect of PTP on guilt ratings. PTP exposed jurors were also more likely to attribute information contained only in the PTP to the trial or both the trial and the crime stories. Collaboration did not significantly affect the rate of these critical SM errors. Again, this is important because these critical SM errors were found to mediate the effect of PTP on guilt ratings.

³ The nested error term was used for all of the F -tests for which there were significant effects of groups nested

EXPERIMENT 2

The second experiment explores the effects of both negative PTP and positive (pro-defendant) PTP on juror decision making. One of the purposes of Experiment 2 was to examine whether positive PTP would increase the percentage of not guilty verdicts and critical SM errors, just as negative PTP increased the percentage of guilty verdicts and critical SM errors in Experiment 1 (Ruva et al., 2007). As mentioned above, research on person perception has found that people pay more attention to negative information than positive information (Fiske, 1980; Meffert et al., 2006; Rozin & Royzman, 2001), which is referred to as the *negativity bias*. This suggests that positive PTP might not have as strong an effect on defendant credibility and juror verdicts as negative PTP. The effects of negative and positive information on source memory are less clear, but the few studies that have included both negatively and positively valenced items found source memory was equivalent for the two types of emotional stimuli (D'Argembeau & Van der Linden, 2004; Doerken & Shimamura, 2001). Therefore, the negativity bias may not extend to memory for the PTP information and its source.

Another purpose of Experiment 2 was to explore how a delay between trial exposure and the source memory test affects jurors' ability to distinguish between PTP and trial information. Although, Experiment 1 found that critical SM errors mediated the effect of PTP on guilt ratings, the rate of these errors was low. It is likely that the SM error rates for actual jurors would be significantly higher because actual jurors are likely to experience much longer delays between exposure to the trial and recall of this evidence during deliberations. Actual trials are lengthy and there could be hours if not days between presentation of much of the trial testimony and deliberation. A recent review of juror utilization in US District Courts revealed that the average length of criminal jury trials in 2002 was 4.3 days (Litras & Golmant, 2006) with the range being 2.2 to 12.3 days. Therefore, in an actual trial there could be 2 or more days between evidence presented early in the trial and the recall of that evidence by jurors during jury deliberations. If trial presentation ends late in the day or late on a Friday this delay could be even longer. Past research has demonstrated that SM errors increase as the delay between encoding and retrieval of a fact increases (Frost et al, 2002) and so we would expect that increasing the time between trial presentation and the SM test would increase the number of critical SM errors.

Method

Participants

The participants were of 159 jury-eligible university students (41 males and 118 females) who received extra course credit for participating in the experiment. They ranged in age from 18 to 31 years ($M = 19.17$).

Design

This experiment utilized a 3 (PTP: negative, positive, or non-exposed) x 2 (length of delay: immediate vs. 2-day) between-subjects design. The cell sizes for these six conditions

were: 54 exposed to negative PTP (28 immediate and 26 delay); 53 exposed to positive PTP (26 immediate and 27 delay); 52 exposed to the unrelated crime stories (24 immediate and 28 delay).

Procedure

The trial, negative PTP, and unrelated crime story stimuli were identical to those used in Experiment 1, and the procedure was similar. The positive PTP (see Appendix A) was added to explore the effect of pro-defendant PTP on juror verdicts and source memory. The experiment consisted of two phases for those in the immediate conditions and three phases for those in the delay conditions. In the first phase, participants were exposed to the PTP (positive or negative) or unrelated articles, in the second phase (5 days later) they were exposed to the trial and rendered individual verdicts. Participants in the immediate condition completed the experiment during Phase 2 by completing the experimental measures in the following order: (1) source memory test, (2) guilt measures (verdicts, guilt ratings, and sentences), (3) ratings of the defendant's credibility, and (4) debriefing questionnaire. Participants in the delay condition returned for phase 3 and completed the measures in the same order as participants in the immediate condition. The only differences from Experiment 1 were: (1) none of the groups deliberated and (2) a delay of 2 days between the trial and the post-trial tasks was manipulated between subjects with participants in the delay condition completing the post-trial tasks in a separate, third experimental phase.

Results

For all analyses the alpha level for significance was set at .05. Log linear analysis of variance for proportions using maximum likelihood estimates (Feinberg, 1980) were used to analyze verdicts. Unless otherwise specified, all other dependent measures were analyzed by 3 (PTP: negative, positive, or non-exposed) $\times$ 2 (length of delay: immediate vs. 2-day) between-subjects ANOVAs. Effect sizes are reported as ω^2 for ANOVAs and as Cramer's V for chi squares.

Guilt Measures

As in Experiment 1, assessment of guilt was measured in two ways, through jurors' verdicts and guilt ratings. In Experiment 2, the verdict measure no longer included a hung option (1 = not guilty and 2 = guilty). PTP had a significant effect on both juror verdicts, $\chi^2(2, N = 159) = 20.65, p < .01, V = .37$, and guilt ratings, $F(2, 153) = 12.69, MSE = 2.81, p < .01, \omega^2 = .13$. As predicted, jurors exposed to negative PTP were significantly more likely to vote guilty and to provide higher guilt ratings than jurors in either the positive PTP or non-exposed conditions (see Tables 5 and 6), $\chi^2(1, N = 159) = 19.52, p < .01, V = .36$ and $F(1, 153) = 23.34, MSE = 2.81, p < .01, \omega^2 = .12$. Also as predicted, jurors exposed to positive PTP were significantly less likely to vote guilty and provided lower guilt ratings than jurors in either the negative PTP or non-exposed conditions, $\chi^2(1, N = 159) = 10.47, p < .01, V = .27$ and $F(1, 153) = 13.08, MSE = .2.81, ps < .01, \omega^2 = .07$. The effect sizes for the effect of negative PTP on the guilt measures are larger than those for the positive PTP effects providing some support for the negativity bias.

Source Monitoring Test, Negative and Positive PTP Errors

The uncorrected mean proportions of SM responses are shown in Table 7, separated into 6 panels as a function of PTP exposure and delay conditions. The first panel reports the SM responses for jurors in the negative PTP immediate condition, the second panel for the negative PTP delayed condition, etc. As in Experiment 1, these mean proportions were not analyzed, per convention. Instead, the corrected scores shown in Table 8 were used in all source memory analyses presented below. The PTP errors of interest were those in which participants misattributed information contained only in the PTP as appearing in the trial or in both the trial and the PTP (Zaragoza & Lane, 1994). There was a significant effect of PTP exposure on both negative and positive PTP errors, $F_s(2, 153) = 45.24$ and 20.11 , $MSEs = .008$ and 0.014 , $ps < .01$, $\omega^2s = .29$ and $.17$, respectively. As predicted, the jurors who were exposed to negative PTP were significantly more likely than positive PTP and non-exposed jurors to misattribute information contained only in the negative PTP to either the trial or both the trial and PTP (see Table 8), $F(1, 153) = 89.94$, $MSE = .008$, $p < .01$, $\omega^2 = .29$. Negative PTP jurors were more confident in these errors ($M = 6.06$, $SD 1.04$) than jurors in the positive PTP or non-exposed conditions ($Ms = 5.04$ and 4.96 , $SDs = 1.49$ and 1.43 , respectively), $F_s(1, 76$ and $69) = 11.35$ and 6.42 , $MSE = 1.67$, $ps < .01$, $\omega^2s = .09$ and $.05$, respectively. Also as expected, those jurors who read positive PTP were significantly more likely than jurors in the negative PTP and non-exposed conditions to misattribute information presented only in the positive PTP to either the trial or both the trial and PTP, $F(1, 153) = 38.47$, $MSE = 0.01$, $p < .01$, $\omega^2 = .17$. Jurors exposed to positive PTP were significantly more confident ($M = 5.94$, $SD = 1.05$) in these errors than jurors in the negative PTP and non-exposed conditions ($Ms = 4.70$ and 4.83 , $SDs = 1.41$ and 1.42), $F_s(1, 66$ and $67) = 15.98$ and 10.62 , $MSE = 1.63$, $ps < .01$, $\omega^2s = .13$ and $.08$, respectively. Also as expected, jurors in the delay conditions made significantly more negative PTP and positive PTP critical source memory errors than jurors in the immediate conditions, $F_s(2, 153) = 42.03$ and 22.64 , $MSEs = 0.01$, $ps < .01$, $\omega^2s = .14$ and $.09$, respectively.

Table 5. Means for the Guilt Ratings for Experiment 2

PTP Conditions				
Delay Conditions	Positive PTP	Negative PTP	Non-exposed	Mean
Immediate	3.65 (1.50)	4.96 (1.64)	3.79 (1.84)	4.17 (1.75)
Delay	3.33 (1.69)	5.19 (1.67)	4.11 (1.71)	4.20 (1.83)
Mean	3.49 (1.59)	5.07 (1.65)	3.96 (1.76)	

Note. PTP = pretrial publicity. Standard deviations appear in parentheses.

Table 6. Frequency Counts and Percentages for Verdicts for Experiment 2

Condition	Not Guilty	Guilty	Total
Positive PTP	39 (74%)	14 (26%)	53
Negative PTP	16 (21%)	38 (70%)	54
Non-exposed	32 (62%)	20 (38 %)	52
Total	88 (55%)	72 (45%)	159 (100%)

Note. PTP = pretrial publicity. Percentages for verdicts appear in parentheses.

Table 7. Mean Proportions of Source Monitoring Responses as a Function of Pretrial Publicity (PTP) Exposure and Delay for Experiment 2

Actual Source				
Response	Trial	Positive PTP	Negative PTP	New
Negative PTP Jurors Immediate				
Trial	.72	.02	.00	.00
Pretrial Publicity	.02	.07	.66	.04
Both	.15	.01	.10	.00
New	.12	.90	.24	.96
Negative PTP Jurors Delay				
Trial	.61	.06	.09	.00
Pretrial Publicity	.04	.07	.46	.00
Both	.17	.02	.21	.00
New	.17	.85	.23	1.00
Positive PTP Jurors Immediate				
Trial	.69	.03	.03	.00
Pretrial Publicity	.03	.78	.11	.02
Both	.17	.07	.02	.00
New	.11	.12	.84	.98
Actual Source				
Response	Trial	Positive PTP	Negative PTP	New
Positive PTP Jurors Delay				
Trial	.66	.07	.02	.00
Pretrial Publicity	.04	.61	.08	.02
Both	.15	.21	.05	.00
New	.15	.11	.84	.97
Non-exposed Jurors Immediate				
Trial	.86	.04	.02	.00
Pretrial Publicity	.01	.00	.00	.00
Both	.00	.00	.00	.00
New	.13	.96	.98	1.00
Non-exposed Jurors Delay				
Trial	.85	.13	.10	.00
Pretrial Publicity	.00	.00	.00	.00
Both	.00	.00	.00	.00
New	.15	.87	.90	1.00

Note: Due to rounding error some table values may not add to 100%.

The significant main effects of PTP and delay on both negative and positive PTP errors were qualified by a significant PTP x delay interaction, $F_s(2, 153) = 15.25$ and 5.40 , $MSEs = 0.008$ and 0.014 , $ps < .01$, $\omega^2s = .13$ and $.09$, respectively. Delay had a significant effect on the proportion of negative PTP errors for jurors in the negative PTP and non-exposed conditions, with jurors in the delay conditions making significantly more of these errors than jurors in the immediate conditions (see Table 5), $F_s(1, 52 \text{ and } 50) = 67.91$ and 4.76 , $MSE = 0.008$, $p < .04$, $\omega^2s = .21$ and $.01$, but only in the negative PTP condition did delay explain a nontrivial amount of variance.

Table 8. Corrected Mean Proportions of Source Monitoring Responses as a Function of Pretrial Publicity (PTP) Exposure and Delay for Experiment 2

Condition	Type of Response		
	Negative PTP Error	Positive PTP Error	Trial Correct
Negative PTP Immediate	.09 (.08)	.03 (.06)	.72 (.12)
Negative PTP Delay	.30 (.14)	.06 (.08)	.61 (.13)
Mean	.19 (.15)	.05 (.07)	.66 (.14)
Positive PTP Immediate	.05 (.05)	.10 (.09)	.69 (.12)
Positive PTP Delay	.07 (.08)	.27 (.21)	.66 (.14)
Mean	.06 (.07)	.19 (.19)	.67 (.13)
Non-exposed Immediate	.02 (.04)	.04 (.06)	.86 (.11)
Non-exposed Delay	.07 (.09)	.11 (.12)	.82 (.07)
Mean	.05 (.08)	.08 (.11)	.84 (.09)

Note. Standard deviations are presented in parentheses following their respective means. Critical source errors include items that were incorrectly attributed to the trial or both the trial and PTP.

Delay also had a significant effect on the proportion of positive PTP critical source memory errors for jurors in the positive PTP and non-exposed conditions, with jurors in the delay conditions making significantly more of these errors than jurors in the immediate conditions, $F_s(1, 51 \text{ and } 50) = 28.10 \text{ and } 4.62$, $MSEs = .014$, $ps < .04$, $\omega^2s = .12 \text{ and } .02$, respectively, but only in the positive PTP condition did delay explain a nontrivial amount of variance. These results suggest jurors' ability to discriminate between the 2 sources of information they were exposed to (i.e., PTP and trial evidence) dramatically decreased over the 2 day delay. Jurors in the delay conditions who were exposed to PTP made approximately 3 times as many PTP critical source memory errors as their no-delay counterparts.

Source Monitoring Test, Correct Judgments of Trial Items

Both delay and PTP had significant effects on correct source memory judgments for trial items (corrected for guessing: as shown in the right hand column of Table 8), $F_s(1 \text{ and } 2, 153) = 9.85 \text{ and } 37.13$, $MSE = 0.01$, $p < .01$, $\omega^2s = .04 \text{ and } .31$, respectively. As predicted, jurors in the immediate conditions accurately identified significantly more of the trial items as coming from the trial than did jurors in the delay conditions. The non-exposed jurors accurately identified significantly more of the trial items as coming from the trial than did jurors in the negative PTP or positive PTP conditions, $F(1, 153) = 73.90$, $MSE = 0.01$, $p < .01$, $\omega^2 = .31$. These differences between the jurors' correct trial judgments appear to result from PTP exposed participants attributing 15% or more of the trial-only items to both the trial and the PTP articles, compared with 0% for the non-exposed participants. These PTP exposed participants discriminated between trial and new items as well as the non-exposed participants, but they did not discriminate as well between trial and PTP information (see Table 7).

Credibility and Attorney Measures

The maximum possible perceived credibility score was 87. As predicted, there was a significant main effect of PTP exposure on jurors' ratings of defendant credibility, $F(2, 153)$

= 14.17, $MSE = 107.25$, $p < .01$, $\omega^2 = .14$. Negative PTP jurors perceived the defendant as less credible ($M = 37.51$, $SD = 10.06$) than jurors exposed to positive PTP or unrelated news stories ($Ms = 48.04$ and 43.71 , $SDs = 9.18$ and 11.59 , respectively), $F(1,153) = 23.71$, $MSE = 107.25$, $p < .01$, $\omega^2 = .12$. In contrast, jurors exposed to positive PTP perceived the defendant as more credible than jurors in the negative PTP or unrelated conditions, $F(1,153) = 18.22$, $MSE = 107.25$, $p < .01$, $\omega^2 = .09$. The effect sizes for the effect of negative and positive PTP on the defendant credibility rating are similar, which is contrary to what was predicted based on the negativity bias in person perception.

There was a significant effect of PTP exposure on jurors' ratings of the prosecuting and defense attorneys, $F(2, 153) = 12.93$ and 3.99 , $MSEs = 14.92$, and 12.99 $ps < .05$, $\omega^2s = .13$ and $.04$, respectively. Jurors exposed to negative PTP rated the prosecuting attorney more favorably ($M = 14.56$, $SD = 3.73$) than jurors in the positive PTP and non-exposed conditions ($Ms = 10.81$ and 12.18 , $SDs = 9.18$ and 11.59 , respectively), $F(1,153) = 22.70$, $MSE = 14.92$, $p < .01$, $\omega^2 = .12$. In contrast, jurors exposed to positive PTP rated the prosecutor less favorably than jurors in the negative PTP and non-exposed conditions, $F(1,153) = 15.09$, $MSE = 14.92$, $p < .01$, $\omega^2 = .08$. The defense attorney received significantly lower ratings from jurors in the negative PTP condition ($M = 13.07$, $SD = 3.81$) than from jurors in the positive PTP and non-exposed conditions ($Ms = 14.94$ and 14.55 , $SDs = 3.68$ and 3.18 , respectively), $F(1,153) = 7.68$, $MSE = 12.99$, $p < .01$, $\omega^2 = .04$.

Mediation Analyses

As with Experiment 1, one of the purposes of Experiment 2 was to explore how PTP imparts its biasing effects on juror decision making. In Experiment 1, negative PTP critical SM errors (negative PTP) and the defendant's perceived credibility were found to mediate the effects of PTP on guilt ratings. The mediation analyses presented below will examine whether these mediational effects replicate and will also explore whether positive PTP critical SM errors and juror's perceptions of the attorneys (attorney ratings) might be mechanisms of the bias effects. To explore the relationships among these variables both the negative and positive PTP critical errors, the defendant's perceived credibility, and both the prosecuting and defense attorney ratings were treated as mediation variables in five mediation models of $X \rightarrow M \rightarrow Y$ (where X is PTP, Y is post-source monitoring test guilt ratings, and M is the mediating variable) (Baron & Kenny, 1986; Shrout & Bolger, 2002).

For the two models with critical SM errors the first equation related guilt ratings to PTP ($X \rightarrow Y$) and was statistically significant, $\beta = 0.79$, $t(159) = 4.91$, $p < .01$ (the first equation is the same for all 5 models and will only be presented here). The second related either the positive or the negative critical SM errors to PTP ($X \rightarrow M$) and were statistically significant, $\beta s = -0.07$ and 0.06 , $ts(159) = -5.46$ and 6.00 , respectively, $ps < .01$. The third equation related the guilt ratings to both PTP and critical SM errors and indicated that for both models PTP was significant, $\beta s = 0.69$ and 0.75 , $ts(159) = 3.95$ and 4.17 , $ps < .01$, and critical SM errors were not, $\beta s = -1.45$ and 0.71 , $ts(159) = -1.41$ and 0.59 , $ps > .56$. The indirect effects of PTP on the guilt ratings via the mediators (positive and negative PTP SM errors) were not significant, Sobel test $z = 1.37$ and 0.59 (1982), $ps > .56$. Therefore, neither positive nor negative PTP critical SM errors mediated the effect of PTP on guilt ratings. This result was unexpected given the significant mediational effect of critical SM errors on guilt rating in

Experiment 1 and may be due to the procedural differences and the significantly smaller sample size in Experiment 2.

Another mediation analysis was performed to test the model of $X \rightarrow M \rightarrow Y$ (where X is PTP, Y is guilt ratings, and M is perceived credibility of the defendant) (Baron & Kenny, 1986; Shrout & Bolger, 2002). The second regression equation related perceived credibility of the defendant to PTP ($X \rightarrow M$) and was statistically significant, $\beta = -5.27$, $t(159) = -5.29$, $p < .01$. The third related the guilt ratings to both PTP and defendant's credibility and indicated the defendant's credibility was significant, $\beta = -0.10$, $t(129) = -9.58$, $p < .01$, and PTP was not significant, $\beta = 0.27$, $t(129) = 4.67$, $p = 0.52$. The indirect effect of PTP on the guilt ratings via the mediator (defendant credibility) was significant, Sobel test $z = 4.55$ (1982), $p < .01$. Therefore, as in Experiment 1 the defendant's credibility ratings significantly mediated the effect of PTP on guilt ratings. The fact that the effect of PTP on guilt ratings was no longer significant after being adjusted for the mediator suggests total mediation.

Two more mediation analyses were performed to test the model of $X \rightarrow M \rightarrow Y$ (where X is PTP, Y is guilt ratings, and M is jurors' ratings of the prosecutor or the defense attorney) (Baron & Kenny, 1986; Shrout & Bolger, 2002). The second regression equation related either the ratings of the prosecutor or defense attorney to PTP ($X \rightarrow M$) and were statistically significant, $\beta_s = 1.88$ and -0.94 , $t_s(159) = 5.02$ and -2.70 , respectively, $ps < .01$. The third equation of each model related the guilt ratings to both PTP and the mediator (either the prosecutor or defense attorney ratings) and indicated that both were significant for both models: (1) model with the defense ratings, $\beta = 0.64$ and -0.18 , $t(159) = 4.26$ and -5.20 , $ps < .01$; and (2) the model with the prosecutor ratings, $\beta = 0.29$ and 0.28 , $t(159) = 2.18$ and 10.78 , $ps < 0.05$. The indirect effects of PTP on the guilt ratings via the mediators (prosecution and defense attorney ratings) were significant, Sobel test $z = 4.55$ and 2.40 (1982), $ps < .05$. Overall, the mediation analyses suggests that the effect of PTP on guilt ratings was mediated by perceived credibility of the defendant and jurors' ratings of the attorneys, but was not significantly mediated by the either positive or negative PTP critical SM errors.

CONCLUSION

The studies presented in this chapter suggest that negative PTP about a defendant can bias both juror and jury decision making. Even though the jurors were admonished not to use information contained in the PTP when making decisions about the defendant's guilt, jurors and juries who were exposed to negative PTP had nearly twice the conviction rates as non-exposed jurors and juries. Experiment 2 found that positive PTP about the defendant also has a biasing effect on juror decision making, with jurors exposed to positive PTP being significantly less likely to vote guilty, and more likely to view the defendant as credible, than non-exposed and negative PTP exposed jurors. Although negative and positive PTP pull verdicts and credibility ratings in opposite directions, both have biasing effects on juror decision making. The negativity bias suggests that negative PTP should have a greater influence on juror decision making and defendant credibility than positive PTP. There was some evidence of the negativity bias for verdicts, guilt ratings, and defense attorney ratings

with negative PTP resulting in greater effect sizes than positive PTP, but this same trend did not hold for defendant credibility ratings.

These experiments also found that PTP exposed jurors were more likely than non-exposed jurors to misattributed information contained only in the PTP to evidence presented at trial, and they were very confident when they did so. The majority of the critical source memory errors for the exposed jurors were due to attributing this information inaccurately to both the trial and the PTP. The jurors did not forget that they read this information in the PTP, but they also believed that they viewed it during the trial. The belief that they had received the information from two separate sources coupled with their high confidence in these source monitoring errors may have made this information extremely influential on their decisions. In Experiment 2, the positive PTP critical source memory error effect was almost identical to the negative PTP critical source memory error effect. These results are consistent with the earlier studies (D'Argembeau & Van der Linden, 2004; Doerken & Shimamura, 2001), in that source memory accuracy was comparable for negative and positive information. Of course, the present study does not have an equivalent neutral condition (the non-exposed participants read unrelated crime articles), but the comparison of source memory errors from positive and negative PTP suggests that both groups experienced difficulty recalling the source of the information.

There were conflicting results for the mediational effects of the critical PTP SM errors on guilt ratings. Experiment 1 found that these errors mediated the effect of PTP on guilt ratings. In contrast, Experiment 2 did not find evidence for this mediation. Although it is not clear why the mediation effect did not replicate, it may be due to methodological (e.g., delay between trial presentation and source memory test and deliberation) and sample size differences between the experiments.

Exposure to either positive or negative PTP influenced jurors' perceptions of the defendant's credibility and suggests that PTP may operate, at least in part, by causing jurors to form either negative (negative PTP exposure) or positive (positive PTP exposure) impressions of the defendant. These impressions may influence the jurors' interpretations of trial evidence and hence their verdicts (Otto et al., 1994) which is consistent with the finding that the credibility ratings of the defendant significantly mediated the effects of PTP on guilt ratings. The findings for the attorney ratings are a little more complicated and suggest that negative information was more influential than was positive information (i.e., negativity bias). That is, exposure to negative PTP influenced jurors' ratings of both the defense and prosecuting attorneys, producing a pro-prosecution bias. Exposure to positive PTP influenced jurors' ratings only of the prosecuting attorney, producing only a weak positive bias. PTP exposed jurors' impressions of the attorneys may have influenced their interpretation of the trial evidence and hence their verdicts, as suggested by our finding that attorney ratings significantly mediated the effect of PTP on guilt ratings.

Now turning to the effects of deliberation on jury decision making, Experiment 1 suggests that these effects depend on how juror bias is measured (e.g., verdicts, credibility ratings of the defendant, SM misattributions). For example, we found that jury deliberation did not have a significant effect on post-deliberation measures of verdicts, guilt ratings, or prison sentences. In contrast, the comparison of predeliberation and post-source monitoring verdicts suggested that group deliberation attenuated the bias associated with negative PTP. Such attenuation has been termed a "leniency shift." Deliberations presumably highlight the law's reasonable doubt standard and the fact that the conviction of the innocent should be

avoided (Kerr, 1993). Although attenuation was found for individual and not group verdicts, it does provide some reassurance for a criminal justice system that relies on juries to eliminate or at least reduce individual biases. Unfortunately, the group verdict is the one that matters in actual trials. Therefore, this reduction in individual bias is relevant only if it affects the group decision or process, which in this Experiment 1 it did not.

Deliberation was also found to increase juror bias in that jurors who deliberated viewed the defendant as less credible than jurors who did not, regardless of PTP exposure. This finding is consistent with past research showing that groups are likely to polarize individual biases held by a majority of group members (Davis, 1992; Davis et al., 1978; Kerr et al., 1999). Experiment 1 suggests that this type of bias is especially important because perceived credibility of the defendant mediated the effect of PTP on guilt ratings.

One purported benefit of utilizing juries is that they are especially good at catching their members' memory errors. Does the deliberation process reduce memory errors? The research presented here cannot directly answer this question because the jurors completed the source monitoring test individually. It can address whether prior collaboration, involving discussion of information contained on a source monitoring test, reduces the number of critical source monitoring errors. We found no difference in the proportion of critical SM errors for jurors in the collaborating and nominal conditions, but we did find collaborating jurors provided more accurate SM responses than did nominal jurors.

Deliberation did not have a significant effect on confidence about critical source memory judgments, but it did significantly affect confidence ratings about trial items with collaborating jurors indicating more confidence in both their accurate and inaccurate source memory judgments. Why the confidence results differed between critical source items and trial items is not clear. It could be that jurors spent the majority of their deliberation time discussing trial items. After all, these items should have been highly accessible because jurors viewed the trial just prior to deliberations. These confidence findings are consistent with past findings that collaboration increases people's confidence in both their accurate and inaccurate memory judgments (Clark, et al., 1990; Stephenson & Wagner, 1989; Stephenson, et al., 1986). These findings are noteworthy because past research has shown that juror participation in deliberations is related juror confidence (Kassin & Wrightsman, 1988) and because juror confidence is not predictive of juror memory (Pritchard & Keenan, 1999) the jurors who participate most in jury deliberations are not necessarily the most accurate (Pritchard and Keenan, 2002). Thus, jury deliberations can bolster jurors' confidence in their inaccurate memories and thereby increase the discussion of inaccurate information. Increased discussion makes it more likely that inaccurate information will become part of the collaborative memory of the trial.

Implications for Legal System

One implication of this research for the legal system is that it may be impossible for defendant to receive a fair trial if their cases involve a large amounts of anti-defendant pretrial publicity. This is because jurors may mistakenly use PTP information to make verdict decisions and may form negative impressions of the defendant before the trial. Another implication of this research is that judicial instructions admonishing juror not to use information contained in the PTP are likely to be ineffective due to jurors' inability to follow

them due to source memory errors or impressions they have formed about the defendant. This research also suggests that jury deliberation is likely to be an ineffective remedy against PTP bias and may in fact increase (polarize) juror bias.

This research also suggests that influential defendants (e.g., Michael Jackson, Martha Stewart, Kobe Bryant) could use the press to bias the jury in their favor, making it more difficult for prosecutors to attain a conviction if jurors interpret evidence in a biased way based on the positive PTP. In the present research we exposed jurors to only one type of PTP (either positive or negative). More research is needed to examine how these two types of PTP may interact. Both sides (prosecution and defense) may try to influence public opinion by providing information that supports their story. Would exposure to both positive and negative PTP result in a level playing field? That is, would exposure to positive PTP moderate the effect of negative PTP on jury verdicts? More research is also needed to examine the factors that affect jurors' ability to discriminate between information they receive prior to trial and facts presented at trial (e.g., length of deliberations; type of case; amount of pretrial publicity; modality of pretrial publicity – written, video, audiotape; and type of pretrial publicity – emotional vs. factual). Given the pervasiveness of PTP, it is important for researchers to continue to explore the mechanisms underlying the PTP bias in order to provide the courts with information they need to make educated decisions about judicial remedies to combat this bias.

APPENDIX A: A SAMPLE OF ITEMS FROM THE PRETRIAL PUBLICITY ARTICLES AND THE SOURCE MONITORING TEST FROM EXPERIMENTS 1 AND 2

Item Type	Sample Items	
	Item 1	Item 2
Negative PTP	Lise Bias' body was found in the doorway of the couple's bedroom.	Lise did not know how to use guns and disliked them.
Positive PTP	Dan and Lise were planning a second honeymoon. The second honeymoon had been Dan's idea.	Dan never wanted a gun in the house, but Lise insisted on having one for self-defense.
Trial	Lise Bias was standing by the mirror when the gun went off.	Daniel Bias had been to the shooting range on the day of his wife's death.
New	Lise' parents had been against her marrying Daniel Bias.	Just prior to his wife's death Daniel Bias was reported to be having an extramarital affair.
Unrelated Crime Stories	One reason the shortages weren't detected sooner was that domestic relations simply wasn't balancing its checkbook on time.	Godshalk took another \$54,493 under another scheme in which she relied on a flaw in a computer program to cover missing money.

Note. The full source monitoring test is available by contacting the first author Christine L. Ruva. PTP = pretrial publicity.

REFERENCES

- Alderton, S. M. & Frey, L. R. (1983). Effects of reactions to arguments on group outcome: The case of group polarization. *Central States Speech Journal*., 34, 88-95.
- Alderton, S. M. & Frey, L. R. (1986). Argumentation in small group decision-making. In R. Y. Hirokawa & M. S. Poole (Eds.) *Communication and group decision making* (pp. 157-173). Beverly Hills, CA: Sage Publications.
- Ayers, M. S. & Reder, L. M. (1998). A theoretical review of the misinformation effect: Predictions from an activation-based memory model. *Psychonomic Bulletin & Review*., 5 (1), 1-21.
- Baron, R. M. & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology*., 51, 1173-1182.
- Bourgeois, M. J., Horowitz, I. A., Fosterlee, L. & Graphe, J. (1995). Nominal and interactive groups: effects of preinstruction and deliberations on decisions and evidence recall in complex trials. *Journal of Applied Psychology*., 80, 58-67.
- Boyll, J. R. (1991). Psychological, cognitive, personality, and interpersonal factors in jury decision making. *Law and Psychology Review*, 15, 163-184.
- Carlson, K. A. & Russo, J. E. (2001). Biased interpretation of evidence by mock jurors. *Journal of Experimental Psychology: Applied*., 7, 91-103.
- Christianson, S. A. & Safer, M. A. (1996). Emotional events and emotions in autobiographical memories. In D.C. Rubin (Ed.), *Remembering our past: Studies in autobiographical memory* (pp. 218-243). Cambridge, England: Cambridge University Press.
- Clark, N. K., Stephenson, G. M. & Kniveton, B. H. (1990). Social remembering: Quantitative aspects of individual and collaborative remembering by police officers and students. *British Journal of Psychology*., 81, 73-94.
- Clark, N. K., Stephenson G. M. & Rutter, D. R. (1986). Memory for a complex social discourse: The analysis and prediction of individual and group remembering. *Journal of Memory and Language*., 25, 295-313.
- Davis, J. H. (1992). Some compelling intuitions about group consensus decisions, theoretical and empirical research, and interpersonal aggregation phenomena: Selected examples, 1950-1990. *Organizational Behavior and Human Decision Processes*., 52, 3-38.
- Davis, J. H., Spitzer, C. E., Nagao, D. H. & Stasser, G. (1978). Bias in social decisions by individuals and groups: An example from mock juries. In H. Brandstatter, J. H. Davis, and H. Schuler (Eds.), *Dynamics of group decisions* (pp. 33-52). Beverly Hills, CA: Sage Publications.
- Davis, R.W. (1986). Pretrial publicity, the timing of the trial, and mock jurors' decision processes. *Journal of Applied Social Psychology*., 16, 590-607.
- Dexter, H. R., Cutler, B. L. & Moran, G. (1992). A test of voir dire as a remedy for the prejudicial effects of pretrial publicity. *Journal of Applied Social Psychology*, 22, 819-832.
- Deitz, S. R. & Sissman, P. L. (1984). Investigating jury bias in a child molestation case. *Behavioral Sciences & the Law*., 2, 423-435.

- Devine, D. J., Clayton, L. D., Dunford, B. B., Seying, R. & Pryce, J. (2001). Jury decision making: 45 years of empirical research on deliberating groups. *Psychology, Public Policy, & Law*, 7, 622-727.
- Doerksen, S. & Shimamura, A. P. (2001). Source memory enhancement for emotional words. *Emotion*, 1., 5-11.
- Feinberg, S. E. (1980). *The analysis of cross-classified categorical data*. Cambridge, MA: MIT Press.
- Fiske, S. T. (1980). Attention and weight in person perception: The impact of negative and extreme information. *Journal of Personality and Social Psychology*., 38, 889-906.
- Frost, P., Ingraham, M. & Wilson, B. (2002). Why misinformation is more likely to be recognised over time: A source monitoring account. *Memory*., 10, 179-185.
- Hans, V. P. & Doob, A. N. (1976). Section 12 of the Canada Evidence Act and the deliberations of simulated juries. *Criminal Law Quarterly*, 18, 235-254.
- Hartwick, J., Sheppard, B. H. & Davis, J. H. (1982). Group remembering: Research and implications. In R. A. Guzzo (Ed.), *Improving decision making in organizations* (pp. 41-72). London: Academic Press.
- Hinz, V. B. (1990). Cognitive and consensus processes in group recognition memory performance. *Journal of Personality and Social Psychology*., 59, 705-718.
- Honess, T. M., Charman, E. A. & Levi, M. (2003). Factual and affective/evaluative recall of pretrial publicity: Their relative influence on juror reasoning and verdict in a simulated fraud trial. *Journal of Applied Social Psychology*., 33, 1404-1416.
- Hope, L., Memon, A. & McGeorge, P. (2004). Understanding pretrial publicity: Predecisional distortion of evidence by mock jurors. *Journal of Experimental Psychology: Applied*., 10, 111-119.
- Imrich, D. J., Mullin, C. & Linz, D. (1995). Measuring the extent of prejudicial pretrial publicity in major American newspapers: A content analysis. *Journal of Communication*., 45 (3), 94-117.
- Johnson, M. K., Hashtroudi, S. & Lindsay, D. (1993). Source monitoring. *Psychological Bulletin*., 114, 3-28.
- Kalven, H., Jr. & Zeisel, H. (1966). *The American jury*. Boston: Little, Brown.
- Kaplan, M. F. & Miller, L. E. (1978). Reducing the effects of juror bias. *Journal of Personality and Social Psychology*., 36, 1443-1455.
- Kelly, A., Carroll, M. & Mazzoni, G. (2002). Metamemory and reality monitoring. *Applied Cognitive Psychology*., 16, 407-428.
- Kensinger, E. A. & Corkin, S. (2003). Memory enhancement for emotional words: Are emotional words more vividly remembered than neutral words? *Memory & Cognition*., 31, 1169-1180.
- Kern, R. P., Libkuman, T. M., Otani, H. & Holmes, K. (2005). Emotional stimuli, divided attention, and memory. *Emotion*., 5, 408-417.
- Kerr, N. L., Niedermeier, K. E. & Kaplan, M. F. (1999). Bias in jurors vs. bias in juries: New evidence from the SDS perspective. *Organizational Behavior and Human Decision Processes*., 80, 70-86.
- Kovera, M. B. (2002). The effects of general pretrial publicity on juror decisions: An examination of moderators and mediating mechanisms. *Law and Human Behavior*., 26, 43-72.

- Kramer, G. P., Kerr, N. L. & Carroll, J. S. (1990). Pretrial publicity, judicial remedies, and jury bias. *Law and Human Behavior*., 14 (5), 409-438.
- Lang, A., Dhillon, K. & Dong, Q. (1995). The effects of emotional arousal and valence on television viewers' cognitive capacity and memory. *Journal of Broadcasting & Electronic Media*., 39, 313-327.
- Lindsay, D. S. (1994). Memory, source monitoring, and eyewitness testimony. In D. F. Ross D. J. Read, & M. P. Toglia (Eds.), *Adult eyewitness testimony: Current trends and developments* (27-55). New York: Cambridge University Press.
- Lindsay, D. S. & Johnson, M. K. (1989). Reality monitoring and suggestibility: Children's ability to discriminate among memories from different sources. In S. J. Ceci, D. F. Ross, & M. P. Toglia (Eds.), *Perspectives on children's testimony* (pp. 92-121). New York: Springer-Verlag.
- Litras, M. & Golmant, J. R. (2006). A comparative study of juror utilization in U.S. District Courts. *Journal of Empirical Legal Studies*., 3, 99-120.
- Loftus, E. F. & Palmer, J. C. (1974). Reconstruction of automobile destruction: and example of the interaction between language and memory. *Journal of Verbal Learning and Behavior*., 13, 585-589.
- London, K. & Nunez, N. (2000). The effect of jury deliberations on jurors' propensity to disregard inadmissible evidence. *Journal of Applied Psychology*., 85 (6), 932-939.
- Meffert, M. F., Chung, S. & Joiner, A. J. (2006). The effects of negativity and motivated information processing during a political campaign. *Journal of Communication*., 56, 27-51.
- Moran, G. & Cutler, B. L. (1991). The prejudicial impact of pretrial publicity. *Journal of Applied Social Psychology*., 21, 345-367.
- Ogloff, J. R. P. & Vidmar, N. (1994). The impact of pretrial publicity on jurors: A study to compare the relative effects of television and print media in a child sex abuse case. *Law and Human Behavior*., 18, 507-525.
- Otto, A. L., Penrod, S. D. & Dexter, H. R. (1994). The biasing impact of pretrial publicity on juror judgments. *Law and Human Behavior*., 18, 453-469.
- Petty, R. E. & Wegner, D. T. (1998). Attitude change: Multiple roles for persuasion variables. In D. T. Gilbert, Fiske, & S. T., Gardner, L. (Eds.), *The handbook of social psychology* (pp. 323-390, Vol. 1). Cambridge, MA: Harvard University.
- Posey, A. J. & Wrightsman, L. S. (2005). Change of venue. *Trial consulting* (pp. 53-78). New York, NY: Oxford University Press.
- Pritchard, M. E. & Keenan, J. M. (1999). Memory monitoring in mock jurors. *Journal of Applied Psychology*., 84, 340-348.
- Pritchard, M. E. & Keenan, J. M. (2002). Does jury deliberation really improve jurors' memories? *Applied Cognitive Psychology*., 16, 589-601.
- Rantzen, A. & Markham, R. (1992). The reversed eyewitness testimony design: More evidence for source monitoring. *The Journal of General Psychology*., 119 (1), 37-43.
- Rozin, P. & Royzman, E. B. (2001). Negativity bias, negativity dominance, and contagion. *Personality and Social Psychology Review*, 5, 296-320.
- Ruva, C. L. & Bryant, J. B. (2004). The impact of age, speech style, and question form on perceptions of witness credibility and trial outcome. *Journal of Applied Social Psychology*., 34, 1919-1944.

- Ruva, C. L., McEvoy, C. & Bryant, J. B. (2007). Effects of pretrial publicity and collaboration on juror bias and source monitoring errors. *Applied Cognitive Psychology*, 21, 45-67.
- Ruva, C. L. & McEvoy, C. (2008). Negative and positive pretrial publicity affect juror memory and decision making. *Journal of Experimental Psychology: Applied*, 14 (3), 226-235.
- Seibold, D. R. & Meyers, R. A. (1986). Communication and influence in group decision-making. In R. Y. Hirokawa & M. S. Poole (Eds.) *Communication and group decision making* (pp. 133-155). Beverly Hills, CA: Sage Publications.
- Shrout, P.E. & Bolger, N. (2002). Mediation in experimental and nonexperimental studies: New procedures and recommendations. *Psychological Methods*, 4, 422-445.
- Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. In S. Leinhardt (Ed.), *Sociological methodology* (pp. 290-312). San Francisco: Jossey-Bass.
- Stebly, N. M., Besirevic, J., Fulero, S. M. & Jimenez-Lorente, B. (1999). The effects of pretrial publicity on juror verdicts: A meta-analytic review. *Law and Human Behavior*, 23, 219-235.
- Stebly, N. M., Harmon, M. H., Culhane, S. E. & McWethy, A. (2006). *Law and Human Behavior*, 30., 469-492.
- Stephenson, G. M., Abrams, D., Wagner, W. & Wade, G. (1986). Partners in recall: Collaborative order in the recall of a police interrogation. *British Journal of Social Psychology*, 25, 341-343.
- Stephenson, G. M. & Wagner, W. (1989). Origins of the misplaced confidence effect in collaborative recall. *Applied Cognitive Psychology*, 3, 227-236.
- Studebaker, C. A. & Penrod, S. D. (1997). Pretrial publicity: The media, the law, and common sense. *Psychology, Public Policy, & Law*, 3 428-460.
- Vollrath, D. A., Sheppard, B. H., Hinsz, V. B. & Davis, J. H. (1989). Memory performance by decision-making groups and individuals. *Organizational Behavior & Human Decision Processes*, 43, 289-300.
- Walker, W. R., Skowronski, J. J., Thompson, C. P. (2003). Life is pleasant—and memory helps to keep it that way. *Review of General Psychology*, 7, 203.-210.
- Weingardt, K. R., Toland, H. K. & Loftus, E. F. (1994). Reports of suggested memories: Do people truly believe them. In D. F. Ross, D. J. Read, & M. P. Toglia (Eds.), *Adult eyewitness testimony: Current trends and developments* (pp. 3-27). New York: Cambridge University Press.
- Wright, E. F. & Wells, G. L. (1985). Does group discussion attenuate the dispositional bias? *Journal of Applied Social Psychology*, 15(6), 531-546.
- Zaragoza, M. S. & Lane, S. M. (1994). Source misattributions and the suggestibility of eyewitness memory. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, 20, 934-945.

Chapter 6

TP-THEORY AS NEW PERSPECTIVE ON COGNITIVE PSYCHOLOGY

Koji Tanida and Ernst Pöppel

Honda R&D Co.,Ltd., Ludwig-Maximilian University,
Munich, Germany

ABSTRACT

Recently, the fact that there is anticipation before cognition in the brain processing is elucidated by brain science, although human behavior has been explained as cognition-judgment-operation loop. The TP-theory (Temporal Predictive behavior model proposed by Tanida and Pöppel in 2006) is a model which applies anticipation-operation-comparison loop as new information processing with temporal frame to human behavior including automobile driving. Why is driving referred? Driving an automobile is an example of a goal-directed activity with high complexity in which different behavioral elements have to be integrated and brought into a sequential order. On the basis of the reafference principle and experimental results on temporal perception and cognitive control, we propose a hierarchical model of driving behavior which can also be adapted to other goal-directed activities. Driving is conceived of as being controlled by anticipatory neuronal programs; if these programs are disrupted by unpredictable stimuli which require an instantaneous reaction, behavioral control returns after completion of the reactive mode to the anticipatory mode of driving. In the model different levels of anticipation windows are distinguished which, however, are interconnected, in a bi-directional way: A. Strategic level with a representation of the driving activity from the beginning to reaching the final goal; B. Segmented tactical level with the sequence of necessary milestones to reach the goal, which are characterized by adaptive scenarios; C. Maneuver – in general operational level, where actions like passing another car or keeping a lane are controlled; this level represents learned activities which have become automatized; D. Short term integration level of two to three seconds, which allows immediate anticipations; this temporal window represents the subjective present; E. Synchronization level for sensory motor control and complexity reduction within neuronal assemblies which allows the creation of mental content and consciously available categories. A flow diagram schematically describes different driving situations stressing the anticipatory mode of control. As mentioned before, this model is able to

apply to riding a motorcycle or a bicycle, cooking, gardening, DIY etc.. This chapter gives the general explanation about the TP-theory.

Keywords: driving behavior, anticipation, feed-forward control, feed-back-control, reafference principle, corollary discharge, temporal perception

“Common sense is the collection of prejudices acquired by age eighteen.”
Albert Einstein

“Brevity is the soul of wit.”
William Shakespeare, "Hamlet"

1. INTRODUCTION

von Holst and Mittelstaedt (1950) wrote down in their article (in German) “Since the neurophysiology was born, the main question is what regular relationship is between an impulse to the central-nervous-system induced by a stimulus and an impulse directly or indirectly returned from the central-nervous-system; between afferent and efferent. It has been well known that there are many facts which cannot be explained by this classical reaction-theory, nevertheless many physiologists think ‘a cause’ of each central nervous event is led only by ‘a stimulus’ ”

And continuing furthermore, “It is very natural that they think so. Because nobody wants to abandon a simple theory from his own motive unless a more excellent theory appears. And furthermore, it is quite natural because it had been regarded as ‘a fact’ for a long time. The characteristic of the concept we newly induced is making a complete change of the point of view by 180 degree. That is, we didn’t raise a question of the relationship between given afferent and its induced efferent; ‘a reaction’, but we conversely examined central-nervous-system using afferent induced through effector organs and receptor organs from efferent (named ‘reafferent’)”.

Their accomplishment was a discovery of anticipation-operation-comparison informational loop replacing traditional cognition-judgment-operation loop. Furthermore there have been many discoveries progressively in brain-science. For example, Pöppel (1997) pinned down the fact that the longest duration of one consciousness is almost three seconds. Thus the characteristics of the brain which controls human behavior and thinking have been elucidated, and then it has been possible to explain theoretically human behavior and thinking. Tanida and Pöppel proposed TP-theory (Temporal Predictive behavior model) using recent brain-scientific and psychological knowledge in order to explain human behavior, thinking, and stress-feeling in 2006.

This new theory serves as a compass to understand human in cognitive psychology and must be helpful for development of artificial intelligence (AI) in application. Here, the TP-theory including the theoretical backgrounds is discussed illustrating automobile driving behavior as one example.



Photo Prof. Dr. Erich von Holst's grave located to the south of Munich, Germany. (German behavioral physiologist and also pioneer of flapping flight, November 28, 1908 - May 26, 1962). Photo by Tanida.

2. THEORETICAL BACKGROUND OF TP-THEORY – THE REAFFERENCE PRINCIPLE

A theoretical frame for the development of an appropriate model is provided by the reafference principle by von Holst and Mittelstaedt, (1950), as it represents operational features which can be generalized for an explanation of complex and hierarchically structured behavior. In fact, the basic ideas of the reafference principle go back to the nineteenth century when both Mach (1885) and von Helmholtz (1896) tried to understand how perceptual stability can be experienced in spite of the fact that the sense organs are stimulated when we move around in the world. Ernst Mach in his seminal book “The Analysis of Sensations” (“Die Analyse der Empfindungen”) made the point, that space perception must necessarily be linked to motor processes. He described that stability of space is only given, if eye movements are under voluntary control. If the eyes are moved passively up and down, objects are no longer experienced as being located within a stable space, but appear to jump in the vertical direction. Similarly, patients who after a brain injury no longer can move their eyes, also experience spatial instability. Apparently, as Mach has suggested, voluntary impulses and visual signal have to be matched to create the apparent spatial ability. (It is obvious that the problem of spatial stability also applies to driving: How is it possible that under normal circumstances we experience the world around us to be stable and we are moving with the car?)

The details of a solution for spatial stability (and other modes of behavior) have been modeled by von Holst and Mittelstaedt (1950) with the reafference principle; in Figure 1 the

basic concept is graphically illustrated. From a higher (strategic) center Z_n a command K is given to a lower center (Z_2); from there a neuronal command is sent to an executive center (Z_1) which in turn innervates (by an efference E) an effector (EFF). Simultaneously, a copy of the efferent command E is put into a store (EK : efference copy). After execution of the movement, an afferent signal A (or the “reafference”) is sent to Z_1 , where this reafferent signal is compared with the efference copy (EK). If A (with a minus sign) corresponds to EK (with a plus sign), both signals cancel each other, and the sensorimotor cycle is completed. If EK and A do not match, a message (M) is sent to Z_2 and Z_n to correct or to re-initiate the sensorimotor cycle until it finally comes to an end. This model refers to short term behavioral acts and explains for instance perceptual stability for the organism. (This concept also may explain behavioral problems: If for instance in a car simulator visual information which simulates the impression of driving for the visual system is not matched by information from the vestibular system because there is no or only very little stimulation of the vestibular receptors, this mismatch of information represents inadequate reafferent information to the organism, and car sickness may be the consequence.)

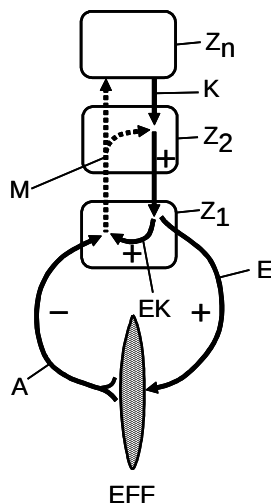


Figure 1. Original concept of the reafference principle by von Holst and Mittelstaedt (1950); the model is meant to explain self-initiated behavior of an organism and it provides a frame for an understanding of spatial stability. (For details see text).

The basic idea of the reafference principle has stimulated a lot of theoretical and experimental work allowing the development of conceptual frames for many behavioral activities. In particular, Teuber (1960) has put the reafference principle into a broader frame by developing the concept of “corollary discharge” which on an experimental basis has been suggested previously by Sperry (1950). Teuber suggested an anticipatory adjustment for all perceptual processes. With this generalization, the general notion of anticipation has been linked to the reafference principle, and it is operationally associated with the efference copy. A command given to the effector system is preserved as a copy within a neuronal assembly (or perhaps in single neurons), and this copy serves as a basis for anticipation. When an action has come to an end, the efference copy is erased, which signals to the organism the

completion of the action, and consequently anticipation or prediction are cancelled. This mechanism enables the organism to distinguish afferent stimulation of the sense organs due to changes in the environment from reafferent stimulation of the sense organs which is due to self produced movements or actions; both stimulations in the extreme case might result in identical patterns of neuronal activities on the receptive surface, but they can be disentangled by the internal monitoring system as described by the reafference principle or corollary discharges.

It has been an experimental question and still is, how the efference copy or corollary discharges might be implemented on the neuronal level. Only recently, a cellular basis of the corollary discharge has been described (Poulet and Hedwig, 2006). A network implementation involving both cortical and subcortical structures has been suggested by Sommer and Wurtz (2004). An essential requirement for a neuronal implementation is the crosstalk between participating neuronal assemblies, and a particular conceptual frame for an interaction between separate assemblies has been suggested by Edelman and Tononi (2000) with the notion of "reentry". They state that reentry is "the fundamental integrative mechanism in higher brains" (p. 102); and later they say that reentry is a process of "ongoing and recursive signaling between separate brain maps along massively parallel anatomical connections, most of which are reciprocal. It alters and is altered by the activity of the target areas it interconnects" (p. 106). Thus, reentry is conceived of being a general format for perceptual organization and motor coordination.

The reafference principle, corollary discharge and the derived notion of anticipation has played in the past and is now playing an increasingly important role in the understanding of behavioral control and also of modeling human behavior. One example is the description of economic behavior and how it might be rooted within neuronal programs by Glimcher (2003); he refers explicitly to the reafference principle. Another example is Hawkins (2004) who in his analysis of intelligence focuses on the importance of prediction; the brain in his view is basically an anticipative organ. Furthermore, in his theory of the development of consciousness Merker (2005) puts the reafference principle into the center of his reasoning. But also in the field of modeling human behavior basic concepts of the reafference principle are included. Körner and colleagues (1997) for instance state that the neocortex constructs a model of the environment and compares the sensory input to this model; after matches between the two have been removed, the "ex-afference" is further analyzed. The perceptual machinery and the interpretation of the percepts are used to generate and verify internal hypotheses. Anticipation is also the key element of a model for perception developed by Gross and colleagues (1999); in their action-perception-cycle they do not separate perception and the generation of behavior as distinct neuronal programs, their goal being "the synthesis of adaptive behavior in truly anticipating sensorimotor systems" (p1127). Besides its importance for general concepts of behavior or for the development of explanatory models, the reafference principle has proved to be also a useful tool in psychiatry. For instance Lindner and colleagues (2005) have observed in schizophrenic patients a high correlation between measures of oculomotor control and disorders of agency; they found that the poorer the efference copy was represented during an oculomotor task, the higher were the problems in the expression of self-reference in such patients. (This extremely interesting result would also indicate that a rather simple psychophysical test might be used for diagnostic purposes.)

In addition to the theoretical and experimental developments as derived from the reafference principle it should be noted, however, that similar theoretical notions have been

formulated like in the TOTE-concept of Miller and colleagues (1960); in this classical analysis the authors state that behavior can be described as a sequence of a test phase (T) in which a subject compares the current state with a goal state; if a discrepancy is registered an operation (O) is initiated to reduce the discrepancy leading to a second test (T); if there are no longer any discrepancies registered, i.e. the behavioral goal is reached, the system goes to the exit operator (E). These previous analyses and models, i.e. the reafference principle, the corollary discharge, the notion of anticipation or prediction, and the TOTE-model provide a useful conceptual background for a model of driving behavior. For such a model it is, however, also necessary to take into account information on temporal perception (Zakay and Block, 1997) as it has already been suggested experimentally how important temporal control can be for safe driving (Nagiri et al., 1994; Uno and Hiramatsu, 1999).

3. THEORETICAL BACKGROUND OF TP-THEORY: INTEGRATED TIME WINDOWS

Human behavior is embedded within many temporal frames which are defined by geophysical cycles like days or years, by the social environment which determines for instance the time of work, or by the neuronal machinery of the brain itself which creates temporal intervals for specific activities (Pöppel, 1997). These temporal frames give structure to behavior, and one such frame is provided by the circadian oscillator (Aschoff, 1965) which determines the phases of wakefulness and sleeping. Looking at the different activities during one day, one observes that many of them represent goal-directed or anticipatory behavior. Such actions may last for several minutes up to hours; examples would be preparing a meal, having a meeting with colleagues, going shopping, giving a talk, doing sports, enjoying gardening, or driving an automobile, a motorcycle or a bicycle to the workplace. All these activities are characterized by similar properties: On a “strategic level” a person has made a decision for a specific activity and has allocated a certain amount of time; such a decision may remain implicit or unconscious as it can be part of the heuristics of regular daily behavior. To successfully reach a goal, lower levels of behavioral control have to be implemented like observing certain milestones in a sequential order, performing specific actions under sensorimotor control, or integrating sensory information within short time intervals. Driving an automobile, a motorcycle or bicycle within such a defined context provides a good example for a better understanding of the different behavioral elements which are necessary to reach an anticipated goal. This aspect of the sequential organization of human behavior (Lashley, 1951), i.e. in particular anticipatory control in traffic behavior, has not yet obtained the attention it deserves in spite of the value of such models like the “zero-risk theory” by Näätänen and Summala (1976) or the “risk-homeostasis theory” of Wilde (1988); in particular the hierarchical organization of temporally embedded control levels should be analyzed in more detail, expanding a view which previously has been given for instance by Summala (1985, 1996) who stressed the hierarchical organization of driving.

One of the biggest challenges of the nervous system is to deal with is the high complexity of neuronal information (Pöppel, 2004). One source of complexity comes from stimulus transduction which is principally different in the sense modalities like audition or vision, taking less than 1 ms in the auditory system and more than 20 ms in the visual system. Thus,

auditory and visual information arrive at different times in central structures. Matters become more complicated by the fact that the transduction time in the visual modality is flux-dependent, i.e. that surfaces with less flux require more transduction time at the receptor level. Thus, to see an object with areas of different brightness or to see somebody talking, different temporal availabilities of local activities within the visual modality and similarly different local activities across the two involved modalities have to be overcome. For intersensory integration besides biophysical problems as given by the transduction times also physical problems have to be considered. The distance of objects like other cars for instance when driving on a highway is obviously never predetermined. Thus, the speed of sound becomes a critical factor. Approximately at a distance of 10 m transduction time in the retina (under photopic adaptation conditions) corresponds to the time the sounds require to travel to the recipient. Up to this „horizon of simultaneity“ auditory information arrives earlier in the brain; beyond this horizon, visual information is earlier. Again, there must be some kind of mechanism which overcomes this temporal problem. Besides biophysical and physical aspects there is a further challenge introduced by the specific brain architecture (Nauta and Feirtag, 1986). As has been shown in neuroanatomical studies there is a large degree of divergence in the projection systems. It has been estimated that each central neuron innervates approximately 10 000 other neurons. This means that local information is spread out over a broad field of receptive neurons and because of the different transmission times along the axons, which is for instance based on the different lengths of axons this local information is not only distributed spatially but it is also spread out over time. A further aspect of complexity is introduced by the mode of functional representation. Experiments using imaging technology like functional MRI indicate that each brain state is characterized by a spatiotemporal pattern of distributed modular activities (e.g., Osaka, 2003). Different modules in the visual modality (being for instance responsible for color or motion perception) are co-activated, and their activity has to be linked. Thus, not only on the cellular but also on the modular level the brain has to deal with integration of spatially distributed and temporally ill-defined neuronal information.

During driving the brain is permanently confronted with changing stimulus situations, and how the brain may overcome this problem of complexity has to be included into a model on driving behavior.

It is suggested that the problems mentioned above can be overcome if the nervous system uses stimulus triggered neuronal oscillations (Pöppel, 1997; Podvigin et al., 2004). One period of such an oscillation is thought to represent the formal basis of an elementary integration unit within which temporally and spatially distributed information is integrated. There is plenty of experimental evidence for such system states in the time domain of 30 to 40 ms; evidence comes from single cell studies in the sensory and motor system, from studies on evoked potentials, from observations on reaction times or latencies in eye movements and from temporal order threshold. Strong support comes for instance from experiments with patients who have to undergo a general anesthesia.

In this situation the oscillatory activity within the neuronal assemblies which presumably represent such system states, is suppressed, the result being that such patients process no sensory information at all. This oscillatory process which is probably implemented in the cortico-thalamic pathway provides a formal framework for complexity reduction, and it is believed to be the neuronal basis for the creation of „primordial events“, i.e., the building blocks of conscious activity (see level E in Figure 2).

On a next level of complexity reduction the primordial events are linked together. Different experimental paradigms suggest an integration interval of approximately 2 to 3 seconds. Experimental support comes from different domains like temporal perception proper, speech, movement control, vision and audition, and also short-term memory. All these observations suggest that neuronal activities are temporally segmented into intervals of a few seconds and that this segmentation is based on an automatic (pre-semantic) integration process providing a temporal platform for conscious activity. It should be stressed that the temporal platform does not have the characteristics of a physical constant but that an operating range of approximately 2 to 3 seconds is basic to mental operations; (obviously, one has to expect some subjective variability for such a temporal integration window).

What is the experimental evidence? If subjects have to reproduce the duration of either an auditory or a visual stimulus one observes veridical reproductions with small variance up to 2 to 3 seconds, and large errors of reproduction with a strong tendency for a shorter reproduction for longer intervals.

It appears as if short intervals can be experienced as a whole while longer intervals temporally disintegrate, i.e., during short intervals of a few seconds it is possible to focus one's attention on specific events.

A qualitatively different paradigm providing further insight into the integration process comes from studies on temporal reversal of ambiguous figures. If stimuli can be perceived with two perspectives (like a vase or two faces looking at each other) there is an automatic shift of perceptual content after approximately 3 seconds. Such a perceptual shift also occurs with ambiguous auditory material, such as the phoneme sequence KU-BA-KU where one hears either KUBA or BAKU; one can subjectively not prevent that after approximately 3 seconds the alternative percept takes possession of conscious content. Temporal integration for intervals of 2 to 3 seconds is also seen in sensorimotor control. If a subject is requested to synchronize a regular sequence of auditory stimuli with finger taps, stimuli are anticipated with very small variance by some tens of milliseconds (Mates et al, 1994; Miyake et al., 2004).

This kind of sensorimotor synchronization is, however, only possible within the operating range of a few seconds. If the next stimulus lies too far in the future (like 5 seconds) it is not possible to program an anticipatory movement that is precisely linked to stimulus occurrence; in such a case movements become irregular and subjects prefer to react to the stimulus instead of anticipating it. Further observations on the duration of intentional movements gave similar numerical values. As these observations are based on qualitatively different experimental or observational paradigms it is proposed that temporal integration in the range of 2 to 3 seconds is a general property of the neuro-cognitive machinery.

This universal integration process is automatic and pre-semantic, i.e. it is not determined by what is processed, but it defines a temporal window within which explicit or implicit activities are implemented (see level D in Figure 2).

Both temporal mechanisms, the one on complexity reduction in a high frequency domain and the other one on temporal integration of just a few seconds have to be included into a model of driving behavior.

4. THE TP-THEORY - HIERARCHICAL AND DYNAMIC STRUCTURE OF GOAL-DIRECTED BEHAVIOR

On the basis of the considerations of the previous two sections it is possible to formulate a hierarchical model of operational anticipation windows in traffic behavior. Although it is predominantly referred to “driving an automobile” the model equally applies to other modes of transportation like riding a motorcycle or a bicycle, and it explains also goal-directed walking behavior in general. In the model five operational levels are distinguished (Figure 2). These levels (A to E) represent different operations from the beginning of driving until reaching the final goal. Level A refers to the long-term perspective on a strategic level where the final goal (with necessary intermediate milestones) is anticipated. Before beginning to drive the purpose of driving and the goal are determined. The driver allocates an approximate time interval for the trip on the basis of previous knowledge of the traffic situation or on the basis of information collected from such sources like the navigation system. To be able to do this a subjective representation of time and the ability to estimate time in advance are required (Zakay and Block, 1997). Level B is embedded within level A and it represents specific milestones to reach the final goal. On this more tactical level specific segments are defined like streets, corners or landmarks that indicate the present position of the vehicle. The driver monitors on this level the performance, i.e. whether the strategic plan to reach the final goal in due time can be maintained; thus, again monitoring of time is necessary (which can be supported by a technical monitoring system). On level C specific maneuvers are represented, again with a shorter time perspective compared to the higher tactical level. On this level driving competence becomes important like passing a car, keeping the lane, or approaching a corner. Whereas levels A and B represent higher cognitive operations, on level C sensorimotor control is required which has been developed individually through driving experience. Novice drivers mainly concentrate their attention to this level, often neglecting the higher levels of operational control. Gaining driving competence means that the driver can maneuver his vehicle effortlessly which allows more attentional resources for the strategic or tactical level; skilled drivers can anticipate better (Kojima, 1995; Nagai et al., 1997). An even shorter term anticipative control level is implemented on level D using the temporal platform of approximately 3 seconds as an operational window. This level provides the behavioural elements which are necessary for the next higher maneuver level. For instance steering the vehicle requires a temporal platform of a few seconds in which the future position of the vehicle is anticipated; if one would react only, the speed of driving would have to be reduced substantially (which under critical situations is actually the case). The lowest level E of this model refers to high frequency neuronal processes in the domain of some tens of milliseconds (see above) that serve short term temporal integration and complexity reduction in the sensorimotor and perceptual systems and, thus, creating also a temporal frame for decisions (Körner et al., 1999). Whereas the low frequency processes (starting with level A) are dominated by explicit representations, higher frequency processes (in particular level D and E) constitute hardware properties of the brain and, thus, remain outside an explicit control. It should be noted, however, that operations on the higher levels of the hierarchy may remain implicit, if for instance certain routes are used regularly allowing the construction of an internal heuristics. Such heuristics allow more effortless driving, and deliberations may occur without paying overt attention to the specific circumstances of the traffic (Dijksterhuis et al.,

2006). Basically, the hierarchical structure of the model integrates both explicit or conscious activities and implicit or unconscious activities; the explicit processes refer mainly to a longer time perspective, (if specific heuristics have not taken over), whereas the implicit processes represent short-term operations of neuronal systems.

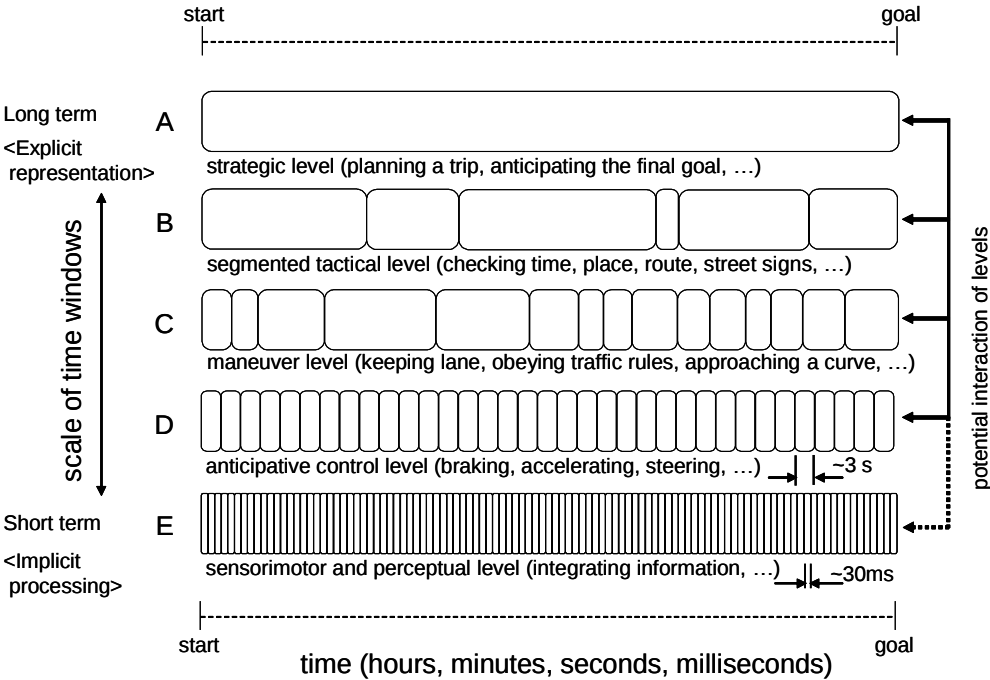


Figure 2. Hierarchical model of operational anticipation windows. Five levels are distinguished from long term to short term control; with the exception of the lowest one all levels can interact with each other in a bi-directional way. (For details see text).

As seen on the right side of the Figure 2, different levels may interact with each other (with the possible exception of level E). Specific driving situations may feed back from level C to B, and to A (for further details see Figure 3), or conversely, the higher levels may modulate the lower operational levels. If on the segmental tactical level a disruption has occurred (like for instance an accident that results in a slowing down of the entire traffic) the driver may have to change his strategy on level A; at the same time he may alter his driving behavior on the maneuver level by trying to pass other cars what he normally would not do. If not enough time has been allocated for the entire trip, level A defines constraints of driving behavior for all the lower levels of operation; the driver may increase his speed to resynchronize with the anticipated milestones on level B, driving behavior will be adapted accordingly on the maneuver level C, and short-term anticipative control on level D draws higher attention.

For all the levels in this model (with the exception of level E which is necessary for providing the mental content and without which there would not be any activity on any of the higher levels) the principle of anticipation applies. On the strategic level the final goal is anticipated, and to reach the goal all the lower levels of anticipatory control are necessary. Thus, the highest level is crucially dependent on the functioning of the lower operational

levels. The purpose of driving could not be kept, if the segmented tactical level, the maneuver level, the anticipative control level, or the lowest sensorimotor and perceptual level would be out of control. Conversely, however, goal-directed driving would not be possible, if a goal would not be defined. Such driving sometimes happens if no purpose is chosen, and the driver just drives to enjoy driving itself. In this case levels A and B are missing or they remain implicit, but the driver is still dependent on the operational levels C, D and E. For goal directed driving, however, a bi-directional influence has to be implemented to allow control of driving and flexible adaptations to specific driving situation.

The importance of anticipatory control in driving is described with a flow diagram in Figure 3 for a specific driving situation. In the beginning a strategy is selected for the entire trip ("start") anticipating the final goal. After an evaluation of the traffic situation, the driver begins to drive. The anticipation of an intermediate goal on the maneuver level (see Figure 2) results in the selection and initiation of a movement program (Grillner et al., 2005); simultaneously, an efference copy is stored. The movement program leads to a driving operation, and the driver receives information on the result of his driving. In parallel self monitoring of the driver is made possible. Next, the anticipated goal is compared with the result of driving and if the anticipation is matched by the result (small difference), the next operation within this feed-forward mode can be entrained. Within this anticipatory mode which is conceived of as being the dominant mode of driving, the subjective state of the driver is a feeling of comfort. If, however, the comparison of anticipation and the driving result leads to a great difference, i.e. if anticipation is violated, a new operational route is opened.

Additional information has to be processed, and within an operational time window a choice has to be made between two alternatives: If there is sufficient time for voluntary control, the driver can immediately go back to the anticipatory mode (left side of Figure 3) having suffered only a short interruption. If, however, there is not enough time for voluntary control, the driver is forced into the reactive mode of driving, or there may be no reaction at all (like in an accident).

If a reaction is possible, new afferent information dependent on the situation will determine further steps. Driving may be continued in a controllable way. If, however, the situation is uncontrollable, adjustment of driving is necessary, or even a new strategy has to be selected. The new strategy may imply to stop driving altogether.

The complementarity of the anticipatory feed-forward mode of driving leading to the feeling of comfort, and the reactive feed-back mode resulting in a feeling of discomfort (major box with the two shaded regions) is embedded within the next operational level (see level B in Figure 2).

The driving situation on the maneuver level is linked to the tactical level, and again on this higher level, anticipation and driving results are compared. A small difference indicates that the driver has reached a milestone, or he has arrived at the final goal. If the driver has not arrived yet, the internal control system of the brain goes back to the general evaluation of the situation (see top of Figure 3). However, if the difference is great, additional information has to be processed, and the feedback loop (resulting in discomfort) brings the internal control system on another way back to the evaluation of the situation. In general, driving in this model is always attracted to the anticipatory mode as this mode provides the neuronal basis for the feeling of comfort.

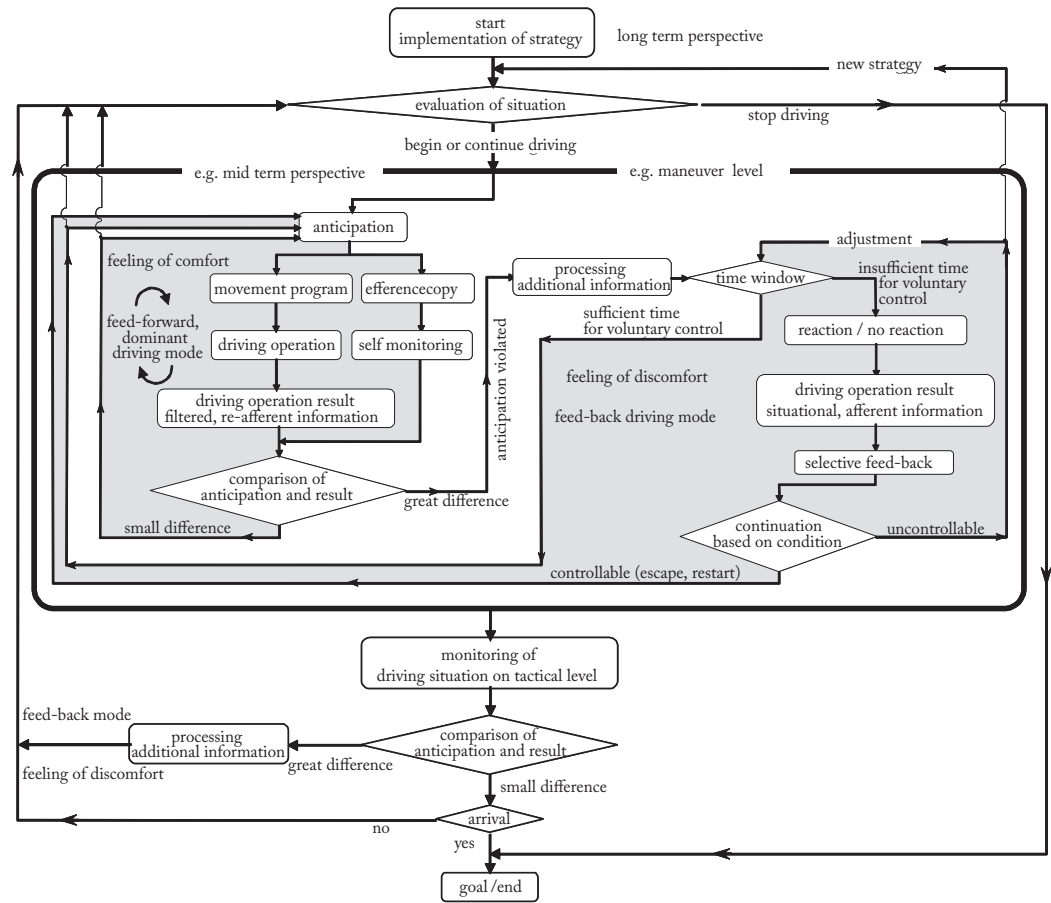


Figure 3. Flow diagram of potential driving situations. Feed-forward and feed-back modes interact with each other; however, the neuro-cognitive machinery is always attracted to the anticipatory mode of driving which is characterized by more effortless processing of information. (For details see text).

Although the anticipatory mode as represented by feed-forward control is a dominant feature of the driving model, the operational openness for feedback control is essential. Feed-forward and feedback control loops also reflect top-down and bottom-up aspects of information processing. Whereas the feed-forward anticipatory mode can also be looked at as top-down processing, the feedback reactive mode can be interpreted as bottom-up processing.

The complementarity of both processing modes is a critical element of this model of driving behavior, and this general notion of a dual control is supported by similar concepts for instance by Desmurget and Grafton (2003) who stress the necessity of an integration of the two loops, by Schill and colleagues (2001) who have suggested the necessity of bottom-up and top-down control in oculomotor behavior, or by Summala (2000) who described these two control modes for specific driving situations. The model presented here goes beyond the different driving models which have been described by Michon (1985). And this model was verified experimentally by Tanida and Pöppel (2006) and already empirically by you readers.

CONCLUSION

As has been outlined above, the TP-Theory provides a new, or in particular a complementary view towards cognitive processing by stressing the importance of anticipation. It can be assumed that the reason why rare items often are missed in visual search (Wolfe et al. 2005) is due to the fact that an anticipatory frame (Pöppel, 2006) is not available. Traditionally, it is assumed that perceptual processes are mainly under the control of sensory input. A famous statement from epistemology says that “nothing is in the mind that has not been in the senses”. Given such a context it is no wonder that in experimental psychology perceptual processes are mainly analyzed by presenting stimuli which a subject can not anticipate. Great care is taken in experimental settings to randomize the occurrence of stimuli. It is believed that one can obtain insight into perceptual processes and cognitive evaluations only or mainly by “surprising” the subject with a stimulus. Thus, one can call this kind of sensory processing “surprise perception”.

It is no question that this paradigm has provided important insights into the cognitive machinery of humans; it is certainly correct to say that using reaction times and their modulations by specific factors has led to a side corpus of knowledge. One such domain of knowledge refers for instance to temporal processing in the range of milliseconds or seconds (e.g. Pöppel 1997, 2004). However does “surprise perception” reflect reality? In fact only rarely are we “surprised” by a completely new situation. Under normal circumstances, perceptions support or confirm what has been already “anticipated”. It is therefore suggested to talk also about “support perception”. One may use a phrase like: “What is new in the world?” reflecting processes in the cognitive machinery which compare an anticipation about a situation with the real situation. This view is one of the main features of the TP-Theory.

The model presented here is not only of theoretical interest by providing an expanding frame for understanding cognitive processes, but is also of practical importance. Obvious scenarios of application are the implementation and control of general strategies (like in economy or politics), a deeper understanding of communication, in particular inter-cultural communication, and also for Human-Machine-Interface (HMI). It is believed that modern ergonomics can only become “cognitive ergonomics” if the anticipatory mode of sensory and cognitive processing is appreciated. If one looks at driving behaviour one can conclude that by including this new way of thinking in the construction of HMI, both comfort will be increased and risk will be decreased.

Essential knowledge for understanding cognitive processing comes from temporal perception (Pöppel 1997, 2004), but also from chronobiology (Aschoff, 1965; Roenneberg and Merrow 2005; Tanaka et al., 1993), from physiological regulations (Tanida, 2001) or from psychological observations (Tanida, 2000; Hotta and Tanida, 2005). Although this knowledge is important in itself it has to be stressed that these different factors play an important role in modulating the different processes on the various levels of the model, but all these factors do not change the structure of the model itself.

If one takes for example “fatigue” as a factor in driving behaviour, one can state that fatigue is strongly influenced by the diurnal rhythm of all functions. As the five different levels of the model are interconnected in a bi-directional way, one may make the following conclusion: First signs of fatigue may effect the operational level, but by doing so, the upper and lower levels of processing are also influenced. Fatigue can result in neglecting tactical

options and possibly missing the initiation of a new strategy. As driving is always goal oriented, the selection of content, i.e. of what is consciously represented can be effected, as attention mechanisms also suffer from fatigue. As a consequence what is processed within the 3-second-window of subjective presence, i.e. what is integrated to allow quick decisions within a short-term frame, will also be affected.

Important new input about cognitive processing comes from research on the representation of our body schema (Iriki et al., 1996; Mararita and Iriki, 2004) or on “embodiment” in general (Pfeifer and Scheier, 1999). This new knowledge suggests a new kind of HMI, and the development of “symbiotic engineering”. The TP-Theory provides a framework to include these important new discoveries. To do so another aspect of cognitive processing has to be mentioned, namely the necessary distinction between the internal point of view and the external point of view. Usually in classical studies in cognitive processing and also in engineering one focuses on the external point of view and explicit information processing. What is usually neglected in such an approach is the internal point of view, sometimes also referred to as the “empathic” relation. Cognitive processing, however, is characterized by both, i.e. having an abstract external view toward a problem and being empathically related to a situation. In the hierarchical model these two modes of subjectivity are represented in such a way that the upper levels (strategy and tactics) emphasize explicit knowledge and the external viewpoint, whereas the lower levels , in particular the second lowest level, provides a framework for the internal point of view or the empathic relation. In particular this level of approximately 3 seconds (Pöppel, 1997) creates a subjective window of presence within which “embodiment” is realized. Man and machine are blended, and a feeling of unity is created that does not require an explicit cognitive representation. This subjective impression of unity of man and machine, of the driver and the vehicle, is the proof of successful symbiotic engineering.

Finally, the TP-Theory may give some useful input into the development of intelligent robots (Moravec, 1988). As has been shown it is essential for advanced robotics to merge top-down and bottom-up processing (Kaku, 1998). As is indicated above the model presented here has included a switch that allows a change between top-down and bottom-up processing, as the flow diagram in Figure 3 demonstrates. Most importantly, the TP-Theory allows the integration of both, bottom-up and top-down processing, thus being open for new information if it is necessary (bottom-up, reactive mode, “surprise perception”), but usually operates in the anticipatory mode (top-down, “support perception”) comparing on the basis of the classical re-afference principle (von Holst and Mittelstaedt, 1950) stimuli as processed in a window of presence with the explicit or implicit goal of action.

REFERENCES

- Aschoff, J. (1965). Circadian Rhythms in Man. *Science.*, 148, 427-1432.
- Desmurget, M. & Grafton, S. (2003). Feedback or Feedforward Control:End of a Dichotomy. In S H Johnson – Frey (Ed.). *Taking Action:Cognitive Neuroscience Perspectives on Intentional Acts* (289-338). Cambridge, Massachusetts: MIT Press.
- Dijksterhuis, A., Bos, M. W., Nordgren, L. F. & van Baaren, R. B. (2006). On Making the Right Choice: *The Deliberation-Without-Attention Effect*. *Science.*, 311, 1005-1007.

- Edelman, G. M. & Tononi, G. (2000). *A Universe of Consciousness. How Matter Becomes Imagination*. New York: Basic Books.
- Glimcher, P. W. (2003). Decisions, Uncertainty, and the Brain. *The Science of Neuroeconomics*. Cambridge: MIT Press.
- Grillner, S., Hellgren, J., Ménard, A., Saitoh, K. & Wikström, M. A. (2005). Mechanisms for Selection of Basic Motor Programs – Roles for the Striatum and Pallidum. *TRENDS in Neurosciences.*, 28, 364-370.
- Gross, H. M., Heinze, A., Seiler, T. & Stephan, V. (1999). Generative Character of Perception: A Neural Architecture for Sensorimotor Anticipation. *Neural Networks.*, 12, 1101-1129.
- Hawkins, J. (2004). *On Intelligence*. New York: Times Books.
- von Helmholtz, H. (1896). *Handbuch der Physiologischen Optik*. 2. Hamburg und Leipzig: Auflage, Verlag von Leopold Voss (in German).
- von Holst, E. & Mittelstaedt, H. (1950). Das Reafferenzprinzip. (Wechselwirkungen zwischen Zentralnervensystem und Peripherie). *Naturwissenschaften.*, 37, 464-476. (in German).
- Hotta, Y. & Tanida, K. (2005). A Study of Driving Behavior when Driver Is Feeling Hurried and a Potential Method for Their Detection. *Transactions of the Society of Automotive Engineers of Japan.*, 36(1), 259-264. (in Japanese).
- Iriki, A., Tanaka, M. & Iwamura, Y. (1996). Coding of Modified Body Schema during Tool Use by Macaque Postcentral Neurones. *Neuroreport.*, 2325-2330.
- Kaku, M. (1998). *Visions*. New York: Anchor Book., 76.
- Körner, E., Gewaltig, M. O., Körner, U., Richter, A. & Rodemann, T. (1999). A Model of Computation in Neocortical Architecture. *Neural Networks.*, 12, 989-1005.
- Körner, E., Tsujino, H. & Masutani, T. (1997). A Cortical-Type Modular Neural Network for Hypothetical Reasoning. *Neural Networks.*, 10, 791-814.
- Kojima, Y. (1995). Driving Characteristics of Novice and Experienced Drivers – Part 1: Characteristics of Visual Search. *Proceedings of the Society of Automotive Engineers of Japan.*, 956, 21-24. (in Japanese).
- Lashley, K. S. (1951). The Problem of Serial Order in Behaviour. In L. A. Jeffress (Ed.), *Cerebral Mechanisms in Behaviour* (pp. 112-136). New York: John Wiley.
- Lindner, A., Thier, P., Kircher, T. T., Haarmeier, T. & Leube, D. T. (2005). Disorders of Agency in Schizophrenia Correlate with an Inability to Compensate for the Sensory Consequences of Actions. *Current Biology.*, 15, 1119-1124.
- Mach, E. (1885). *Die Analyse der Empfindungen und das Verhältnis des Physischen zum Psychischen*. Jena: Gustav Fischer., (in German).
- Maravita, A. & Iriki, A. (2004). Tools for the Body (Schema). *Trends in Cognitive Sciences.*, 8, 79-86.
- Mates, J., Radil, T., Müller, U. & Pöppel, E. (1994). Temporal Integration in Sensorimotor Synchronization. *Journal of Cognitive Neuroscience.*, 6, 332-340.
- Merker, B. (2005). The Liabilities of Mobility: A Selection Pressure for the Transition to Consciousness in Animal Evolution. *Consciousness and Cognition.*, 14, 89-114.
- Michon, J. A. (1985). A Critical Review of Driver Behavior Models: What do we Know, what should we Do?. In L. A. Evans, & R. C. Schwing (Eds.), *Human behavior and traffic safety* (487-524). New York: Plenum Press.

- Miller, G. A., Galanter, E. & Pribram, K. (1960). *Plans and the Structure of Behaviour*, New York: Holt, Rinehart and Winston.
- Miyake, Y., Onishi, Y. & Pöppel, E. (2004). Two Types of Anticipation in Synchronisation Tapping. *Acta Neurobiologiae Experimentalis.*, 64, 415-426.
- Moravec, H. (1988). *Mind Children*, Harvard University Press.
- Näätänen, R. & Summala, H. (1976). *Road-User Behavior and Traffic Accidents*. Amsterdam: North-Holland.
- Nagai, M., Onda, M., Miyamoto, N. & Kojima, Y. (1997). Driver Characteristics in Winding Roads in Mountains. *Proceedings of the Society of Automotive Engineers of Japan.*, 975, 177-180. (in Japanese).
- Nagiri, S., Doi, S., Takei, K. & Mizuno, M. (1994). Experimental Analysis of Avoidance Maneuver Using Driving Simulator. *Proceedings of the Society of Automotive Engineers of Japan.*, 941, 17-20. (in Japanese).
- Nauta WJH & Feirtag M (1986) *Fundamental Neuroanatomy*. Freeman, New York.
- Osaka, N. (2003). Working memory-Based Consciousness. An Individual Difference Approach. In N. Osaka (Ed.), *Neural Basis of Consciousness* (pp. 27- 44). Amsterdam: John Benjamins Publishing Company.
- Pfeifer, R. & Scheier, C. (1999). *Understanding Intelligence*. Cambridge: MIT Press.
- Poulet, J. F. A. & Hedwig, B. (2006). The Cellular Basis of Corollary Discharge. *Science.*, 311, 518-522.
- Podvigina, N. F., Bagaera, T. V., Boykova, E. V., Zargarov, A.A., Podvigina, D. N. & Pöppel, E. (2004). Three Bands of Oscillatory Activity in the Lateral Geniculate Nucleus of the Cat Visual System. *Neuroscience Letters.*, 361, 83-85.
- Pöppel, E. (1997). A Hierarchical Model of Temporal Perception. *TRENDS in Cognitive Sciences.*, 1, 56-61.
- Pöppel, E. (2004). Lost in Time: A Historical Frame, Elementary Processing Units and the 3-Second Window. *Acta Neurobiologiae Experimentalis.*, 64, 295-301.
- Pöppel, E. (2006). Der Rahmen. Ein Blick auf die Landschaften des Gehirns. München: Hanser-Verlag. (in German).
- Roenneberg, T. & Merrow, M. (2005). Circadian Clocks – the Fall and Rise of Physiology. *Nature Reviews.*, 6, 965-971.
- Schill, K., Umkehrer, E., Beinlich, S., Krieger, G. & Zetsche, C. (2001). Scene Analysis with Saccadic Eye Movements: Top-down and Bottom-up Modelling. *Journal of Electronic Imaging.*, 10, 152-160.
- Sommer, M. A. & Wurtz, R. H. (2004). The Dialogue between Cerebral Cortex and Superior Colliculus: Implications for Saccadic Target Selection and Corollary Discharge. In L. M. Chalupa, & J. S. Werner (Eds.), *The Visual Neurosciences* (1466-1484). Cambridge: MIT Press.
- Sperry, R. W. (1950). Neural Basis of Spontaneous Optokinetic Response Produced by Visual Inversion. *Journal of Comparative and Physiological Psychology.*, 43, 482- 489.
- Summala, H. (1985). Modeling Driver Behavior: A Pessimistic Prediction? In L. Evans, & R. C. Schwing (Eds.), *Human Behavior and Traffic Safety* (pp. 43-65). New York: Plenum Publishing Corporation.
- Summala, H. (1996). Accident Risk and Driver Behaviour. *Safety Science.*, 22, 103 – 117.
- Summala, H. (2000). Top-Down and Bottom-Up Processes in Driver Behavior at Roundabouts and Crossroads. *Transportation Human Factors.*, 2, 29-37.

-
- Tanaka, S., Ueno, S. & Takeuchi, S. (1993). An Examination of Visibility in Night Driving. *Journal of Traffic Science Society of Osaka.*, 22, 15-22. (in Japanese).
- Tanida, K. (2000). Reducing the Effects of Driving Fatigue with the Adoption of a Lane Following Assistance System. *Society of Automotive Engineers of Japan Review.*, 21, 258-260.
- Tanida, K. (2001). Attempt to Identify Panic in Terms of Heart Rate Acceleration Response during Braking. *The Japanese Journal of Ergonomics.*, 37, 159-168. (in Japanese).
- Tanida, K. & Pöppel, E. (2006). A Hierarchical Model of Operational Anticipation Windows in Driving An Automobile. *Cognitive Processing.*, 6, 275-287.
- Teuber, H. L. (1960). Perception. In J. Field, H.W. Magain, & V. E. Hall (Eds.), *Handbook of Physiology-Neurophysiology III* (1595-1668). Washington, DC: American Physiological Society.
- Uno, H. & Hiramatsu, K. (1999). Relationship between Time Margin and Driver's Steering Avoidance in an Emergent Situation. *The Japanese Journal of Ergonomics.*, 35, 219-227. (in Japanese).
- Wilde, G.J.S. (1988). Risk Homeostasis Theory and Traffic Accidents. Propositions, Deductions and Discussion of Recent Commentaries. *Ergonomics*, 31, 441-468.
- Wolfe, J. M., Horowitz, T. S. & Kenner, N. M. (2005). Rare items often missed in visual searches. *Nature.*, 435, 439-440.
- Zakay, D. & Block, R. A. (1997). Temporal Cognition. *Current Direction in Psychological Science.*, 6, 12-16.

Chapter 7

LEARNING STRATEGIES AND APPROACHES OF UNIVERSITY STUDENTS: THE CHALLENGE OF THE 21ST CENTURY

Nora Irene Abate*

Universidad Nacional de Tucumán, Argentina

ABSTRACT

This work is based on a research on the learning strategies used by the students who attend the last year at the faculty of Psychology at the National University of Tucuman, in Argentina. In the different levels of education, several problems have been observed in the learning processes. The cognitive approach provides the suitable theoretical framework to include/understand and to analyze the learning strategies. The hypothesis of this research was that the general average of the qualifications obtained by the students of the fifth year of the university career of Psychology is related to the usage of learning strategies: acquisition, codification, recovery and support. The examples are supported by the application of a scale of learning strategies, (ACRA) of Roman and Gallego (1994), in a random sample of students who attended the fifth year in the career of Psychology. The conclusions allow asserting that some students preferably used the strategies of acquisition and codification, as a way of learning limited to the requirements of the task that allowed them to pass the subject. However, the others used all the strategies, preferably those of recovery and support. That is to say, that besides learning they know how to do it.

The results allowed me to verify the hypothesis and to establish the positive and meaningful relation between the averages of the results and the learning strategies. The importance of these findings will allow reframing the processes of teaching and learning with the idea of training a critical, reflective and strategic student. Key words: Learning Strategies of teaching and learning.

* Corresponding author: Magister of Educational Psychology, Professor of Educational Psychology; Professor of Cognitive Psychology, Researcher. Pablo Rojas Paz 78, capital San miguel de Tucumán, CP : 4000, Tucumán, Argentina, personal telephone number: 03814353477, office telephone number : 0381156096228, noraabate@arnet.com.ar

INTRODUCTION

The society of the 21st century, marked by relativism, uncertainty and transience of knowledge is a challenge for education. In educational research, an idea that comes with a lot of weight is to define it as a society of knowledge and information. As a consequence of scientific, technical, economic and social development, the knowledge changes rapidly. It is a highly competitive society which considers it essential that students develop in learning to think, relate and understand, in addition to acquire, develop, organize, retrieve and use knowledge. Therefore, the challenge it presents to education is a path of change in the training process towards a student's profile that uses its resources effectively and strategically, i.e., to form students to guide their knowledge towards learning goals, so that, faced with a situation they know what to do, with clear awareness of how, when and why, according to *The New Culture of Learning*. (Well and Monereo, 1999) Fernando Sabater's assertions in his book *The Value of Education* are instructive about the new ways of learning: "The ability to learn is made of many questions and some answers, of personal searching and not of institutionally imposed findings, and criticism and doubt rather than satisfied obedience to what is commonly established" (Sabater, 1997: 50)

However, the different levels of education are full of obstacles in the learning process. In this regard, UNESCO, in 2002, undertook an investigation in 41 countries on five continents, to learn the ability of students at the age of 15m faced with the challenges the contemporary society will propose in different areas of the knowledge. The results obtained in our country show the difficulty to respond to the instructions in reading and critical analysis of texts and thoughtful writing and understanding. They also show difficulties in linking prior knowledge with new information since they are only able to make connections with their basic everyday knowledge. (UNESCO, 1999)

According to this scenario in the new millennium, higher education is immersed in economic, political and social issues, that complicate the future of the institution and the future of classroom practices. University, focusing on the model of traditional education, based on the accumulation and transmission of knowledge, should be oriented to improve processes of thinking, reflection and understanding, within the framework of different disciplines. (Litwin, 1997)

HYPOTHESIS

The overall average scores of students in fifth year of the career of psychology is related to the use of learning strategies: acquisition of information, strategies for encoding information, information retrieval and support processing.

PART ONE: LEARNING

Historically, the education has been associated with understanding the processes of teaching and learning. The different theoretical approaches, from cognitive to asociacionism have tried to explain how students learn.

The topic of the strategies is related to the learning process, which is why it is essential to clarify this term, since the concept of learning that is supported will depend on how the strategies are understood. (Well and Monereo, 1999)

According to this premise and the theoretical path that has been taken it is possible to observe between the different authors, substantial overlap of the meaning of learning, but it is also necessary to emphasize that it is impossible to provide a universally accepted definition, which is integrated into a unified theoretical framework to account for all internal and external phenomena that often tie in with the concept.

One of the concerns in education today is that the student leaves the storage of data, dates and names, leaving aside the literal repetition, by seeking to reason, reflect and understand what he's learning. In this sense, it seeks to give meaning to themselves what they learn and establish relationships between knowledge and learning with the new information it is presented.

In the learning process, students build relationships between new information and prior knowledge, you can organize and monitor the entire process, as you can think and reflect about the stages by means of learning strategies.

STRUCTURES OF COGNITIVE SYSTEM: MEMORY

The structural components will now be described: the memory and its systems: sensory register, short-term memory, long-term memory; and the diagrams. Both components will help to understand how the cognitive system works and how learning strategies act.

The memory function outstands for the preservation of history and culture in the world; at the dawn of humanity, when people were not able to write, memory was the only records of the culture. Its function was merely repetitive: keep history through stories. The memory is involved in every act of our life, without memory it is impossible for a subject to interact with reality, with himself and with others. If we stop for a moment to remember what we did the day before or remember what we did an hour earlier, the report will come as the mechanism that allows us to recall, relive events, anecdotes from our lives, knowledge learned earlier, that are stored in it. Studies of the memory date back to the late nineteenth century, precisely in 1879 Ebbinghaus (1850-1909) German philosopher began studying human memory in an experimental way. Its purpose was to study objectively the human memory, based on an associationist approach and empirical knowledge. In Germany, "The School of Verbal Learning" continues the line of investigation proposed by Ebbinghaus.

From another perspective, one can mention the research by Frederick Bartlett, English psychologist, who in his book "Remembering" (1932), outlines the position of the subject and his activity towards the learning task. He explains the essential role of memory as a constructive process that occurs at the confluence of different variables: the area where the task is done, the properties of the material that must be learned, prior knowledge of the subject and its age. This position is antagonistic to the experimental and simplistic conception of memory that Ebbinghaus had proposed. Instead, Bartlett gives a different nuance, while continuing the experimental line; he adds the importance of memory prior to each subject

in relevant enviromental conditions.

This leads to consider a fundamental aspect of memory, its constructive nature, i.e. that those things human beings assimilate from the environment are not as shown by reality; instead, a change is made on the basis of what they already own and the new information incorporated. A central concept that uses Bartlett is "scheme", this concept has already been used by Henry Head (1920) in the field of Medicine and Bartlett takes it to the field of psychology, to refer to experiences that we have of the world and that form a set of models, from which we interpret and conceptualize the different events. During recent decades, studies about memory have recovered the central importance that it had in the learning process, and mainly in research on learning strategies. The memory for this stream of thought is defined as the capacity that human beings have to record, retain and retrieve information.

So, the information that we receive from the environment we have to withhold it through some strategies so that it is save in our memory. If it is not stored properly, then we will not be able to remember when necessary. These strategies play different roles: the acquisition is the process by which information is recorded in the half, the initial coding to organize the information so that our memory system can be used. Another of the processes of the memory system is the storage, it consists on saving the information in the memory and keeping it until we need it. Recovery can find the information you have stored in the forms of knowledge. These strategies are essential for understanding how the learning process works. The acquisition, encoding, storage and recovery, are required to carry out the learning process, but they do not describe by themselves what happens to the information from the moment it reaches the sensor system until it is kept in our memory. The answer to this question is given by two studies that referred to the memory system. The first explains how the memory works departing from three systems and they vary in their function and the processes that are activated. (Atkinson and Shiffrin, 1968). The second suggests that the information passes through different levels of processing: deep and superficial. (Craik and Lockhart, 1972).

THE MODEL ATKINSON AND SHIFFRIN

In general, the following pages will present the theoretical developments on the report from the perspective of the multi-store theory by Atkinson and Shiffrin (1968) and then refer to the contributions of the theory of levels of processing by Craik (1979) and Craik and Tulving (1985). In this sense, the memory system is shown in its functional aspect and its importance in the development, implementation and execution of strategies for learning. It should be clarified that the multi-store theory is not the only effort to develop studies concerning memory and its processes. His choice is based on that it is compatible with the theoretical foundation of the art of the Learning Strategies Scales, ACRA. (scale acquisition of information, level of encoding information, scale information retrieval and scale of support for Roman and Gallego, 1994)

With the cognitive picture of the fifties and the approach of information processing emerged with Atkinson and Shiffrin (1968) the multi-store model of memory. In this model, the memory is regarded as formed by interconnected systems: the sensory register or sensory memory (RS), the short-term memory (STM), and long-term memory (LTM). Within the broad field of memory studies, different authors have proposed different names, for example: semantic and episodic memory, Tulving (1979), declarative and procedural memory,

Anderson (1982), implicit and explicit memory, Schacter and Graf (1985). For the purpose of this work, it will be developed, as announced previously, the multistore-model proposed by Atkinson and Schiffrin (1968), there are also studies by Waugh and Norman (1965) and Hunt (1971) that now have broad validity.

While the emphasis of this model is on the structural analysis of the report, it stressed the procedural aspects, such as acquisition, consolidation, storage and retrieval of information, precisely because these functional mechanisms are behind the process and the learning strategies that are used. These allow the transmission of information and to establish relationships between systems.

In this model, it is considered that the structure of the human mind is a system for acquiring and processing information consciously. A characteristic feature is the conscious control processes and control processes, especially in the review of STM. The structure of the report responds to *a basic architecture of the human mind*, which describes stages in the acquisition of information, from the existence of these interconnected systems, where information stays for a certain time in each of them. This leads to differences in functions and abilities between different systems. (Carter, 1997; Pozo, 1998, Baquero, 2001). Here are the characteristics of each of the memory systems, including an emphasis on cognitive processes that develops our minds to transfer knowledge from one system to another.

SENSORY MEMORY OR REGISTRATION

It is in this record where attentional strategies are activated, which allow you to select, process and transport the information from the sensory register to the short term memory and there the strategies of repetition are placed to keep information until it is transferred to long-term memory.

They are input filters that constitute an element of the memory system that are associated with the senses, particularly with the perception. Their function is to keep the information for very short periods of time, about half a second. This memory consists of different registers according to the sensory modalities, so, it is possible to distinguish between a sensory echoic memory and a sensory iconic memory, the first is related to the auditory information and the second to visual information, there is also a haptic record for the tactile information. (De Vega, 1990, Navarro Guzmán, 1993)

The sensory system keeps the details of the information collected and since the information has not been influenced by the categories of the subject, it is presented in a primitive state; it is therefore a precategorical record. The sensory memory allows the recognition of sensory stimuli, the information received can be transferred to the short-term memory or it is forgotten, and in this case it is lost.

SHORT-TERM MEMORY

The information that comes from the sensory system is selected to move to another structure: the STM. It is in this system where the strategies of fragmentation and repetition are activated, allowing the persistence of information until it is transferred to the LTM.

Turbey (1973) suggests that from the sensory system the information is transferred first to a device called of selection and categorization, so that not all information enters into the system, operating a selection so that only information that is considered relevant to the STM arrives.

The STM is characterized by retaining a limited number of units of information. In the reference literature it is mentioned the work of George Miller *The Magical Number Seven* (1956). This book is a symbol within the developments of cognitive psychology, as it states that the capacity of short-term memory is seven, plus or minus two items or units of information. Determining in this way a limited capacity for memory, but related to the context and task. (Carretero, 1997)

The STM not only has its limitations in storage capacity, but it also has limitations in the period in which the information is. Therefore another aspect that characterizes the STM is that a stock is transitory. Thus, the information may be withheld in a structure which is called seal or review buffer for a few seconds, but if it is not transferred, it is forgotten or, if we hold it any longer we must put into action the strategies of repetition. A clear example that helps to explain it is the attempt to retain a phone number; if it is not written on paper, or strategies are used to remember it such as memory techniques or rhymes, the number is forgotten.

It is therefore essential to consider that as it is a transient system and of limited capacity, it is easily saturated with a lot of information. Therefore, if the information presented is dosed and well organized, the learning will be more effective.

FUNCTIONS OF THE SHORT-TERM MEMORY (STM)

The STM is defined as a complex structure that fulfills different functions, such as mechanism of retention of information and as a functional memory. (De Vega, 1990)

a) STM as a Mechanism of Retention of Information

The STM is considered as the system that receives the information that comes to the subject through the senses, which uses the encoding strategies, retention and retrieval of information on a transitional basis.

As mechanism of retention, the functions that characterize it are: the retention, forgetting and recovery. The importance of understanding these features is projected onto the teaching-learning process, given that this limitation can be overcome using strategies of development or organization.

The STM has already been regarded as a limited stock in its ability to retain information units: one of the potentials for increasing its capacity is the formation of chunks, i.e. groups or mergers of common units or pieces of information. These units or chunks can vary according to the properties of information and preparation of the material done by the subject. In this sense, the units of information can be letters, numbers, words or phrases, you should be aware that this is not physical but psychological units, whose complexity and size can vary, and depends on how the subject develops the information. (De Vega, 1990; Pozo, 1998)

The Condensation in the chunks of information is used to organize it and make it meaningful. In the base of this process underlies the idea of understanding, as a process that the subject uses in the mechanisms of grouping, and not just an association with another element. One advantage is that it encourages learning in an automatic way, given that cognitive mechanisms are activated in a rapid, accurate way and thus it increases the operational efficiency of the STM. An example of this in learning is that if you want to increase the number of units of information to process, then you must provide instances of trial in order to develop or group them, and thus expanding the capacity of the STM and avoiding excessive demands.

Regarding the role of retention and forgetting, it is necessary to remember that in previous pages it was raised the limit of time and retention of information in the STM.

Some studies state that the time for withholding information is relative and it varies from 15 to 30 seconds. The period of retention time is difficult to establish because other factors may allow the persistence of information for a while longer: the strategies of repetition and review. There are two theories to explain forgetting: on the one hand, the theory of the temporary impairment, according to which, the information disappears with the passage of time and on the other hand, the interference theory of forgetting, which states that the entry of new information in the system moves the already established one. (De Vega, 1990) This allows us to understand when students explain the difficulty presented by the amount of information you need to learn in the limited time they are offered. Information retrieval is another function of the STM along with the retention and forgetting. When the information is still in the STM, you can recover instantaneously because the units of information are aware and active in this process of recognition memory. The STM is also involved in the process of retrieving information from the LTM. This is a complex and dynamic process that depends on the strategies of development and organization.

HOW THE STM WORKS

Taking up some of the features already listed, we can affirm that the STM is a structure which can be implemented in different processes and it fulfills several functions: active control, coordination, organization and implementation of the information coming from both the sensory register and from the cognitive system itself. These are functions that allow the acquisition of new information and the use of prior knowledge. (De Vega, 1990; Pozo, 1998) In the control operations performed by the CCM it employs different strategies: repetition, retrieval of information from the LTM and execution of complex cognitive tasks. (De Vega, 1990)

The strategies of repetition allow the persistence of the material in memory for a longer time than it is usually achieved and the transfer of information units to the LTM. This transfer function is very important in the learning process, since the strategies and organizations from which the combination and integration processes will allow information to be filed within the overall structure of the LTM; i.e. in the patterns of knowledge, to be retrieved when necessary. From this it follows that it is necessary to establish meaningful relationships between what we want to file and the rest of the knowledge already stored in the long term, this step is key to the learning process. This can be seen in students in examinations; they

were asked about prior knowledge learned in other subjects that are relevant to the current situation but they showed that they "forgot" that knowledge.

It is in the CCM where the confluence and integration of information coming from the sensory register with the one that comes from the LTM takes place.

The processes of integration of information are made through re-encoding operations and image formation.

- **Recoding:** This process is described by George Miller (1956), it involves expanding the capacity of the CCM. It is achieved by grouping the information in chunks that occupy little space, but have a lot of information. Recoding is called "chunking", it consists in forming a new code. I.e., that knowledge that is stored in the LTM is encoded in the STM when it is a knowledge that is related to it.
- **The formation of images and memory techniques:** the method of "loci" from Ancient Greece was used to memorize long speeches. It consisted in thinking a place and giving a space in the imaginary place to the item to be learnt. To remember, from this approach, would mean to go mentally to that place. It provides learning strategies such as organizing information, repetition and review. Another method applied is the memory technique, through a keyword; it uses rhymes that are associated with images of what we remember.

Both recoding and image formation are embedded in processes that establish meaningful relationships between new information and knowledge stored in the LTM and elements of the information being recalled (Cabezas, 1987). The knowledge of these processes has important implications for learning as we often hear students claim that information is excessive and the time is short, so, knowing the importance of strategies such as memory techniques, imaging, recoding, and organizational development, leads to an appropriate use of cognitive resources in the teaching-learning process.

To summarize, the STM is involved in the execution of complex cognitive tasks, in this sense and from the above considerations it follows that the STM is an active warehouse where functions as repetition and recoding are executed: the first allows to retain the material in the STM for a longer period of time and if it is accompanied by encoding it allows to transfer this information to the LTM. The second comes from the interaction of the STM and the LTM, which allows the material to relocate and expand the capacity of the CCM.

In this context, the storage capacity of STM is not automatic, it is a conscious process and it involves the functions of retention, replication, recovery and re-encoding.

LONG-TERM MEMORY (LTM)

The information that remains in the LTM is usually off and latent and it only becomes active according to the necessities imposed by the task or the context; this recovery process takes time and effort.

The system uses cognitive strategies to incorporate and store information so organized in our system of LTM so that when you need it it can be restored quickly in order to make learning effective and lasting.

The LTM has no limits on your storage memory, it is information we saved during our whole life as an archive of our life. So that, for example when we look at a picture that has some years, it triggers the memories that remained in the LTM. Some authors believe that this system has two components: episodic memory and semantic memory (Tulving, 1983). Episodic memory is used to store the events of our life experiences and lessons. Semantic memory, in turn, stores the knowledge we have about the world.

But not all information that is filed with the LTM is recoverable, as the memory has a selective function: What is not unused is forgotten. It also allows reconstructing the learning but depending on current needs, therefore, memory is an active system that constructs and reconstructs knowledge depending on the requirements of our cognitive system.

Different authors, including De Vega (1990) and Navarro Guzmán (1993) find that the LTM also involves oblivion, and to explain it he takes the basis of proposals from Baddeley ([1982, 1990]). This author proposes two possible explanations: first, we forget the effect on time that produces the fading of the print, the second is the theory of interference, which occurs in the oblivion of the retention period, when it incorporates new information to the existing one and oblivion is produced by the interference. The information is coded and transferred from the STM to the LTM, it operates a replica of semantic information, and this means that when studying a text, in that moment you are able to give precise details of dates and events, however after some time you are able to remember the general idea of the text. We do not remember exactly, since this system does not encode superficial aspects of the information, but semantic aspects. This will mark a difference between the STM and the LTM, the first memory is literal and immediate, whereas the second recalls general aspects and fragments of information.

In this sense, we can say that in the LTM the following systems operate:

- Selection: Essential aspects are remembered and the rest is forgotten or modified.
- Interpretation: It remembers according to what we believe happened.
- Integration: It unites aspects of prior learning with new ones that are saved.

The LTM, while a warehouse that can store more information, concepts in the MLP seem to be organized in the form of propositions, which are statements that have a subject and a predicate (e.g. "the canary is a bird"). These propositions form networks to which we are continually adding new concepts. Authors mentioned above (De Vega, 1990; Navarro Guzmán, 1993) believe that networks of concepts are organized hierarchically and they form categories, so that when you store a concept such as "pine" it is related to the category of conifers and the category tree. In turn, these networks can activate concepts related to the similarities or differences. The construction of these networks is of fundamental importance in the learning process, it demands from the students an active position, the use of strategy and organization and from the teacher that the information would be presented clearly and accurately.

Bower (1975) noted that in the LTM there are structures such as:

- Space models of the environment, including representations relating to images of objects and places.
- Concepts of objects and their properties.
- Beliefs about people, ourselves and ways of social interaction.

- Attitudes and values towards events and social objectives.
- Motor skills, problem solving and understanding of the language, music and painting.

According to Gagné and Glaser, (1987) although Bower's list is broad enough there are other elements in the LTM that deserve special attention, such as images, declarative knowledge (know what) procedural knowledge (how), patterns and cognitive abilities. The following sections will develop these concepts. To characterize memory systems, we can say that although they have different functions, they are in constant interaction, i.e. the functioning of the sensory register is related to the CCM and it can never be considered isolated from the operation of the LTM. The path taken shows the importance of these systems in the learning process. Undoubtedly, the research carried out regards the importance of maintaining the strategies in the processing of information, both the storage and acquisition, as the recovery and control of information, emphasizing the need to establish meaningful relationships between new information and the one that is already stored in our memory. Thus, there is an effective learning process, lasting and meaningful.

THE SCHEMES

It is important for this piece of work to explain how the schemes are involved in the processes of representation, acquisition, encoding and retrieval of knowledge.

There will be a revision that will help to understand what the schemes are their roles in knowledge representation and the strategies involved here.

The various investigations in the field of cognitive psychology attempt to explain that the knowledge that individuals possess of the world is represented and organized in our cognitive system. This knowledge is stored in the LTM. It is organized into a set of schedules.

These representations of knowledge are the ways in which they are reported internally and they organize the information coming from the subject's relationship with the outside world, with objects and people, throughout their lives.

They are not exact copies of reality, they imply active processes in the processing of information that enters the system, and they are the result of constructive processes that take place in the schemes.

Originally the term schema in the field of psychology comes from Europe, with Piaget (1926) and Bartlett (1932) that independently led to the idea of schema. Prior to this date in 1920, lays the notion of schema in the field of medicine with Henry Head.

Piaget used it to explain the thinking in children; however Bartlett used it in studies of memory and understanding, in social areas. However, this notion is recovered long after by information processing psychologists and especially those employed in the development of artificial intelligence.

The work of Sierra and Carretero (1996) and Carretero (1997) marked differences with a genetic psychology notion of schema. In this regard, they consider that diagrams are representations of the different fields of knowledge and they are likely to be completed to the extent that more information may be included with each pattern forming subschema. When the schema is activated, it becomes a guide to find information to fill gaps and build a coherent and complete interpretation. If there is no additional information, a subschema can

be constructed with the inferences made from the information we have about the situation in particular, the typical example is the "restaurant schema" (Carter, 1997). This means that generally, anyone ever attended a restaurant so in the LTM this pattern is present, which allows us to predict what may happen, for example the waiter comes, he gives the table, he brings the menu, we choose food and we follow all the usual steps. However, if there is a fast food restaurant, this scheme does not allow generic behavior in a location with different characteristics and therefore a subschema must be built to act differently, depending on the situation. As a summary, below there are some general features that all the schemes theories share:

1. They are high-level cognitive units: units that include simpler units, e.g. dressing includes clothing, shoes.
2. The components of the schedules are updated, modified or varied, depending on the context e.g. dressing for a party is different from dressing to work, both clothing and shoes etc.
3. Multifunctional schemes: the importance and usefulness of the schemes is large. This is demonstrated in the processes of understanding and retrieval, and retrieving the information from the system and the related knowledge that are stored in the schemes.
4. Training Scheme: the pattern formation of the mechanism is unknown, what is argued is that it is formed from the experience.

The schemes are involved in the higher psychological processes: perception, comprehension and memory. From the literature (Carretero and Sierra, 1996, Carretero, 1997, Pozo 1998) there are different names referring to the content of knowledge, and we can also mention the terms schema, script (scripts), frames (frames) and mental models.

The schemes, as stated above, are guides whose function is to guide and direct the process of construction and reconstruction of information. This knowledge representation schemes in long-term memory is related to how to organize and structure the knowledge of what is the role played by diagrams in teaching and learning and consequently in understanding of strategies for acquisition, encoding and retrieval. (Well, 1996, 1998, Carter, 1997) In general, it is argued that knowledge representation schemes present the following features:

- The contents that make up the schemes with respect to an object, situation or concept are activated together, as they are related, so that when you activate one of the components, it activates the rest.
- They are organized into holistic units, responding to a temporary organization and they are grouped by interrelated subunits.
- The knowledge that remains is stored in three types, declarative knowledge, procedural knowledge, and finally the strategic knowledge and conditional knowledge. Here we deepen the characteristics of knowledge: declarative, procedural and conditional or strategic.

STRATEGIES AND KNOWLEDGE

The learning strategies activate different types of knowledge that are in the schemes: the declarative, procedural and conditional or strategic knowledge. The declarative knowledge is knowledge that can be explained, it refers to "what it is", it is general and specific, covering the background that we possess of the world and things. Procedural knowledge, also called procedural, it refers to "how something is done" it is the specific knowledge of the strategy, it is related to the actions that must be followed to achieve the goal, the practical components; it is a know-how. Pozo (1998), Postigo and Pozo (2000) argue that the declarative knowledge is conscious and it is acquired verbally; procedural knowledge instead is acquired through action, the practice of gradual and progressive manner, it tends to be automatic. Knowing the importance of this knowledge in the learning process allows understanding the difficulties students face in their tasks.

More specifically, it may happen that students solve a problem, but they can not explain or define what kind of knowledge is required. Thus returning to the initial approach that holds that "say" and "doing" are two different ways to know the reality, but they are necessarily linked. (Entwistle, 1988; Pozo, 1998; Postigo and Pozo, 2000) Then this development will be completed with a third kind of knowledge, which in literature is called conditional knowledge or strategic knowledge, which encompasses the above and it includes the knowledge of "when" and "why" to apply this or that strategy. It is knowledge on the specific circumstances that influence the use of certain strategies for achieving a goal. The three types of knowledge lead in turn to different types of learning and the use of different strategies. (Well, 1998; and Monereo Castelló, 2000) In associative learning, you go from declarative knowledge to procedural knowledge automatically. It is a kind of learning that is convenient when it is not necessary to make associations among contents; learning is repetitive and superficial. However, when the declarative knowledge is related to procedural and conditional knowledge, the student can explain what he knows, how, when and in what circumstances and why you should apply this or that strategy. According to this approach, one can say that learning is profound, intentional, targeted to understanding and besides it is strategic in connection with the personal variables, the type of task and context in which it develops. For example, when reviewing a text the student can establish connection between similar concepts previously studied cases and infer which approach is needed or if you require other texts to revise and extend the concept to understand.

ROLES OF THE SCHEMES

The cognitive systems exchange information with the reality; they construct representations of reality that are filed in the LTM. These representations of knowledge are organized into schemas, and refer to all domains of knowledge, these schemes are being built throughout our lives, they are active and they allow us to give sense and meaning to what surrounds us. The function of schemas in memory processes is related to the encoding process (Brewer and Nakamura, 1984) and also with the recovery process. (Rumelhart and Ortony, 1977).

Coding

Several authors, De Vega, (1990) Sierra (1996), Carretero (1997) have described this process. They consider that the role of coding is essential in guiding the selection, abstraction, interpretation and integration that occur when new information is acquired. How do the schemes proceed to memorize the contents?

As explained earlier in the section of the memory systems, the cognitive system receives a variety of information, which encodes only one part, one that has relevance to the system or the enabled scheme. The process is as follows: it abstracts the meaning of the information that enters the memory system, it is interpreted according to the schema activated and it interacts with the background remaining in the system. The strategies of coding involved in the preparation and organization of new information establish relationships with prior knowledge. Otherwise, if there is no prior knowledge, the information is lost or retention is minimal and superficial. (Ausubel, Novak and Hanesian, 1973) Thus, the selection process within the coding is understood [...] *as an application or projection of the new content on existing knowledge; the application depends largely on the availability of a sufficient base of knowledge and well developed.* (Sierra, and Carretero, 1996:150).

The schemes involved in the process of abstraction recover the significant aspects and discard the surface, so that only selected information is recorded and those aspects of the format or presentation details such as lexical and syntactic forms are discarded. The schemas interpret the information received from inferences about the information selected. (Sierra and Carter, 1996:151)

Integration processes faced with the acquisition of new knowledge get involved in the modification of the existing scheme or in the formation of a new scheme, some of the forms that are mentioned are:

- Addition, it incorporates new knowledge to the scheme
- Restructuring, it reorganizes knowledge schema
- Formation of a new scheme, it is integrated when the contents of some knowledge representation consists of an overview that contains them.

RECOVERY

The schemes are involved in the process of recovering the contents stored in the LTM; this statement can be found in different authors. (Sierra and Carretero, 1996 Carretero, 1997; Pozo, 1998)

Recovery strategies are actively involved in the schemes that reinterpret information already stored and thus modify or restructure the original information. (Sierra and Carretero, 1996). In recovery, the processes of selection and verification get involved in the existing schemes to determine which is appropriate to integrate the new knowledge. The development carried out shows that:

- The diagrams are representations of all domains of knowledge.

- Each pattern can be formed by sub schemes; this refers to the specialization of knowledge in each domain.
- Their different functions cover different processes: understanding, memory and conduct.
- They have an impact on the processes of encoding and retrieval.
- They explain and interpret the phenomena that other theories had left aside.
- They highlight the active and dynamic nature of the acquisition, encoding and retrieval of information and therefore, they explain the use of learning strategies.

THE THEORY OF THE LEVELS OF PROCESSING BY CRAIK

This theory provides an alternative theoretical explanation to the multi-store model of Atkinson and Schiffrin, since during the learning process, it becomes difficult to distinguish where one or the other acts. In this sense, the knowledge we have is not saved in rigid compartments, given that when new information is added to the system it activates the connections with other knowledge already stored. It should be added that these relations will be superficial or deep according to the strategies put into play.

However, while highlighting the contributions of the theory of levels of processing by Craik, you can not discuss the importance of the differentiation of memory systems:

[...] The conclusions reached by research on levels of processing memory is reinforcing the need for improved strategies for control and storage of information by students, establishing relationships between what they already know and what we want to teach. (Carter, 1997:141)

The research that has been conducted helps to understand the importance of the functional aspect of the memory and the actions and proceedings conducted by the students to recall information. (Well, 1996) In this sense, the interest is directed to examine how information is processed and which are the possible stages of processing.

According to this theory, what determines the remembrance is the nature of encoding processes as determinants of relative permanence of the information. In this sense, they consider the memory as a unitary system that has different levels of processing: structural, phonological and semantic levels that occur in the sensory perception and pattern recognition, to the attribution of meaning. In other words, what are stored on a permanent basis are traces of information arising from the processes of coding, focusing primarily on operations of perception and understanding. The qualitative differences of these processes are the ones that allow a determination of good or bad addition of the information in our memory system. (De Vega, 1990).

For the authors, the memory is an active process and it is not an information store. The theory of levels of processing emphasizes the degree and quantity of information to be processed. The central point in this theory would be the use of strategies of revision that would allow a deeper learning. Consequently, a difference is presented between development revision and maintenance revision. The first means a greater level of depth in the information processing and it provides higher level of performance than the second, since it tries that

information remains in the system. Thus, the nature of the processes is given more importance than the time of permanence of the information in the memory.

On the other hand, what this theory of the levels wants to explain in relation to learning is the importance of coding strategies that are made, an example of this are the investigations of intentional learning and incidental learning, which compares the performance of learning tasks between groups of experts and novices. We show that if cognitive processes are the same what make the difference are the strategies that are used. (Navarro Guzmán, 1993).

In learning tasks, it is possible to consider levels in the process, a surface level that is based on sensory and physical characteristics of the information. It refers to the features related to the structure of the information that is based on the strategies of repetition and learning by heart: for example if we read the word table, attention is paid to the shapes of letters. It recognizes an intermediate level in the process that concerns the nature of phonological features, i.e. the physical characteristics of words and adding the sound units corresponding meaning. In contrast, in the deep level of processing one learns best, in a meaningful or comprehensive way, allowing the analysis of the concepts in relation to the meaning given, building relationships and partnerships with stored information and knowledge in a wider context.

In general we can say that the theory of levels of processing considers a number of assumptions:

- There is no difference among the systems but in the amount of information processed.
- Different standards can be considered in information processing: deep and superficial, the differences lays in that each one involves different strategies that lead to different levels of understanding.
- The information that we learn best is the one that is processed at a higher level of depth. Consequently, the deeper levels of analysis allow such information to be more elaborate, comprehensive and meaningful.
- The repetition or memorization of the information does not assure that it is transferred to the LTM.

Pozo Municio emphasizes the importance of levels of processing in learning, proposed by Craik and Tulving, saying:

[...] the more significant or deeper processing and learning materials are, the more durable and general are the results. Understanding is the best alternative to the review. (Municio Pozo, 1998:267)

The contributions of this theory lead to one of the best known classifications within the learning strategies: deep and superficial, and it is related to investigations conducted by Entwistle (1988) and Marton (1981) for educational work in the classroom. These authors claim that it is possible to differentiate approaches to learning: surface, deep and strategic, related to the intentions of the students in completing the learning tasks. According to research done, the two theories have implications for learning.

The multi-store-model of Atkinson and Shiffrin said that the memory system is composed of three different systems: sensory memory or register, short-term memory and long-term memory, each having different attributes. While the theory of levels of processing by Craik

and Lockhart refers to the degree of processing that occurs after we receive information of the stimuli until they are stored in long-term memory (LTM), which involves different strategies. The memory is not a passive system, but it depends on the treatment that the subject does with the information. Thus, both theories contribute to understand the strategies necessary to ensure a process of reflexive, comprehensive and meaningful learning.

DIFFERENT APPROACHES TO LEARNING

Cognitive research in recent decades is becoming important in analyzing the learning processes that students use in the classroom. In this sense, it highlights the research done by F. Marton his collaborators and the University of Gothenburg and Noel Entwistle at the University of Edinburgh. These authors find that in one group of students, it is possible to establish differences in the degree of understanding achieved. (Entwistle, 1988:65)

Accordingly, it is possible to distinguish approaches in addressing the tasks of learning, which are primarily based on the concept that the student is learning and intention with which they perform that task. In the use of approaches underlay the implementation of learning strategies. (Coll, 1988; well Munici, 1996.1998).

In the surface approach, the student focuses on the task, he expresses the intention to remember the material from which there is an increase in knowledge by literal repetition and memorization of information. The student plays a passive role towards information, objectives and tasks are nominated by someone else, in this case can be the teacher. The task is imposed, the treatment of the material relates to the external aspects, it does not establish relations with other knowledge, the task is completed, and soon forgotten. In the deep approach the student seeks the construction of personal concepts and the search for the meaning of what they are learning, the intention is aimed at developing relations between knowledge, comparisons. He is personally and emotionally involved with the task, it is an essential part of his personal life. The intent is aimed at linking and organizing the study material with previous knowledge, for which the student has an active and critical role.

On the other hand, Entwistle (1988) incorporates a third approach: the strategy that combines both approaches depending on the requirements of the task, adding that the student seeks or achieves success in the proposed tasks which are planned and well organized; proposing clear objectives for learning, which organizes the time and the effort to achieve better results.

Accordingly, for the purposes of this work, it should be noted that these approaches are linked to different conceptions of learning and use of strategies. (Pozo Municio, 1998, 1999, Roman and Gallego, 1994) Thus, the approach involves a superficial associative learning in which strategies are used for the acquisition and consolidation, particularly the development of simple strategies. In the deep learning approach predominates the use of constructive strategies for complex development, organization and retrieval. In the strategic approach dominates the strategic learning and support strategies.

LEARNING STRATEGIES

One of the concerns in education today is that the student leaves the storage of data, dates and names, leaving aside the literal repetition, by seeking to reason, reflect and understand what he's learning. In this sense, he seeks to give meaning to himself and what he learns and to establish relationships between knowledge and learning with the new information that is presented.

It is the cognitive approach that helps to understand the processes used to learn, these developments lead to change old practices that led the students to repeat long poems, memorizing numbers and formulas, by the quest for autonomy in planning and responsibility for learning.

Early studies can be placed around the fifties, the so-called cognitive revolution. These studies aim to develop systems for solving problems, new procedures arise like acrostics, the memory techniques and other techniques used to recall and review, to prevent forgetfulness. A number of educational programs emerge on the scene, exercising the application of techniques to learn, or recipes for the study, called "How to study", which emphasize the repetition in an easy automatic way. (Well and Monereo, 1999)

Authors such as Castelló and Monereo, (2000) highlight that it is in the eighties when the study and research of learning strategies are secured in the field of Cognitive Psychology.

Since then several studies and research are presented on learning strategies and metacognition, problem solving in a given area of knowledge with experts and novices. (Carter, 1997; Pozo, 1998; Monereo and Pozo, 1999).

Other authors working in contexts where the problems arise are the example of educational research in the classroom. The tasks that students perform largely include what information is selected from the environment and how it is processed. The tasks organize the experience; therefore, researchers need to refer to the environment in which these tasks are developed. (Carter and others, 1998).

The word strategy derives from the military field. In this area it is defined as "the art of coordinating military forces in order to win a war." The concept became known to the area of politics, economy and all areas of knowledge; it is precisely in the educational field where it has become a key concept and fundamental to understanding the learning process. According to the theoretical support of this work and then by an extensive bibliography of reference, it presents the following definition of learning strategies:

[...] Those sequences integrated processes, which are used for the acquisition, storage and retrieval of information with the aim of learning where cognitive processes are activated in a conscious, deliberate and intentional way. Thus, the strategies of learning are intimately connected with the motivation and metacognition. The strategies relate to the knowledge of what, how, when and why they do it, they are activated depending on the learning goal and the characteristics of each discipline. (Abate, N: 2006).

Learning strategies that have certain characteristics that should be clarified because if they are viewed as processes that apply in an intentional and deliberate way to a task, it can not be reduced or confused with automatic routines or techniques: these are the visible parts of the strategies; for example, highlight the text, finding the main idea, drawing up schemes.

To implement the strategies the following conditions are required on the psychological functioning:

- A knowledge or metacognition of the own psychological behaviour.
- The awareness of its existence
- The motivation, intentions and goals. Self monitoring and evaluation of actions based on that goal.

CLASSIFICATIONS OF STRATEGIES ACCORDING TO THE PROCESSES INVOLVED: ACQUISITION, CODING, RECOVERY AND SUPPORT

This classification comes from a working hypothesis put forward by the Roman authorities and Gallego (1994) who consider that the main cognitive processes relate to the acquisition, encoding, storage and retrieval. Following this line of thought, it is possible therefore to distinguish learning strategies that are activated for the acquisition, encoding and retrieval. A central contribution is the support strategies (Dansereau, 1985) pertaining to the implementation of processes of social and metacognitive nature.

In recent decades, research on learning strategies emphasize the importance of studies on the memory on which it is defined as the capacity that human beings have to record, retain and retrieve information.

The emphasis of this model is on the structural analysis of memory and procedural aspects such as acquisition, encoding, storage and retrieval.

The acquisition is the process by which information of the environment is recorded, while the encoding allows organizing the information initially, so that our memory system can be used. The storage consists of storing information in memory and keeping it until we need it. Recovery can find the information you have stored in the forms of knowledge. While the processes of support refer to conditions in which the learning processes are based, including non cognitive and metacognitive nature. At the same time they help or enhance the performance of other strategies.

Below is the classification of strategies proposed by Roman and Gallego (1994), which is to be used in this research:

- 1) Acquisition Strategies: Strategies include attention and repetition.
- 2) Coding strategy: to include memory techniques, preparation and organization.
- 3) Strategies for recovery: they include search and response generation.
- 4) Strategies of support include the metacognitive and social ones.

Acquisition Strategies

In these strategies, the attention is the central process, which allows "selection, processing and transportation of the information from the environment to the registration of the senses." (Gallego and Román, 1994:8)

The structure of the human mind is a system for acquiring and processing information consciously. A characteristic feature is the process of conscious control, especially control review processes, which occur in the CCM.

Within the acquisition strategies there are different attentional strategies and repetition. They are based on the associative learning and they provide a superficial approach.

Coding Strategies

The encoding process gives a code to the information, it presupposes a degree more or less deep and it leads to the understanding and meaning.

The function of these strategies is also to collaborate with the passage of the information present in the STM to the LTM, i.e. after the execution of the processes of attention and repetition are the processes of elaboration and organization of material. Its purpose is to look for relationships between materials previously saved with the new information that is incorporated and integrated into broader meaning structures. (Román and Gallego, 10:1994)

The strategies of coding referred to the memory techniques, preparation and organization.

Organizational strategy refers to a higher level of complexity and it is a profound approach to the meaning they build; conceptual structures from which they establish the relationship between knowledge. Organizational strategies play a key role in the recovery process. In this sense, it depends on the quality of internal relations and connections are established between new knowledge and those that remain in memory, to be able to achieve an adequate recovery. The organization of the information depends on the characteristics of the student, the nature of the subject, the context of aid and the teacher. (Well, 1998; Monereo, 1990) Both, the development strategies and the organization strategies put into action a series of cognitive processes including: selection of relevant information, relationships with prior knowledge, production of meanings within a semantic hierarchy and consistency, integrated into the structure of knowledge in each subject.

According to the points made above, the student plays an active position in dealing and processing of information, as these strategies impose a high degree of personal involvement with the material. That is, these strategies create a conceptual metacognition, developing personal information and allowing further reflection on their own processes of understanding. This step is central to a better use of the learning process. (Nisbet and Shucksmith, 1997).

Recovery Strategies

Once the information is processed, the subject must be able to recover and remember the knowledge that is stored in the LTM. The information that remains in the LTM is usually latent and inactive, it is activated only in accordance with the requirements imposed by the task or context, this recovery process takes time and effort. The various investigations carried out in the field of cognitive psychology try to explain that the knowledge that individuals possess of the world is represented and organized in our cognitive system, in a set of schemes. (Carterretero, 1997; Pozo, 1998) Thus, the selection in the coding process is defined as:

...] An application or projection of the new content on existing knowledge; application depends largely on the availability of sufficient and well developed knowledge. (Sierra, and Carretero, 1996:150)

We can say that the cognitive system uses strategies to incorporate information and store it in an organized way in our system of LTM, so that when you need it it can be restored quickly in order to make learning effective and lasting. We use the following processes:

- Selection: Essential information is remembered and the rest is forgotten or neglected.
- Interpretation: Information is recalled according to what we believe happened
- Integration: It unites aspects of prior learning with new ones that are saved.

Strategies encourage the search for information on schemes and the connection of those events, or facts to the present moment. (Gallego and Román, 1994) Its function is to reinterpret the information already stored and thus modify or restructure the original information of the schemes. (Sierra and Carter, 1996)

In recovery, the selection processes involved and verification taking place in the existing schemes determine which is appropriate to integrate the new knowledge. The implementation of strategies for encoding, presupposes the storage as a constructive process and recovery, and reconstruction as a process which is put into operation in the organization and reorganization of concepts.

Support strategies

Within this category there are social strategies and metacognitive strategies, both supporting strategies. During the processing of the information processes involved in nature and not metacognitive knowledge can help or interfere with the learning process due to external and internal factors that interact. Among the strategies are the socio-emotional, social and motivational, involving key aspects that influence both the learning process and its outcomes. Among the aspects that include the socio emotional strategies it can be mentioned for example the time control, organization of learning environment, management and control effort, social interaction, motivation, among others. These strategies are stated by Román and Gallego (1994).

[...] Support and enhance of the performance of acquisition and the recovery increased motivation, self-esteem and attention. (Gallego and Román, 1994:15)

Its purpose is to improve the material and psychological conditions in which learning occurs. Keeping this in mind, we can say that in the process of learning, there are important motivating factors, interactional and affective, that are as important as the cognitive ones. Among support strategies there are also metacognitive strategies, the study of this issue is central to the research on learning strategies. (Well and Monereo, 1999; Mateos, 2001). In the 70s John Flavell introduced the term metacognition to describe one's awareness of cognitive processes. Initially the researchers were interested in studies of metacognition in

relation to memory, thus it can also be found in the literature the term metamemory reference. Referring to this concept, Nisbet and Shucksmith (1997) propose the following definition:

[...] Metacognition is the term that designates the ability to learn the knowledge, thinking and reflecting on how we react or respond to a problem or task. " (Nisbet and Shucksmith, 1997:55).

SECOND PART: THE METHOD

The methodology used was quantitative. The logic of quantitative research points to an objective knowledge, rigorous product and hypothetical deductive method. In this sense, it involves the search for general explanations, through a statistical treatment of data.

Participants

The participants were students who were enrolled last year in the career of Psychology, at the National University of Tucumán, Argentina. The elected population of students ($N = 136$) attending the fifth year in 2002 were a randomly selected sample consisting of 105 students ($n = 105$) of both sexes, of different ages ranging between 22 and 26, who joined in 1998. This sample was chosen because it was considered that cognitive strategies are evolutionary and contextual, as noted by Paris "it is acquired with the exercise, you can learn it and teach it." (Paris, 1983: 93).

Instrument

The range of learning strategies (ACRA, Román and Gallego, 1994) consists of four subscales: level I strategies for acquiring information; level II strategies of encoding information; III scale retrieval of information and level IV strategies to support the prosecution. (ACRA).

The booklet is for individual use and it allows each student to read the material carefully and to take the time to answer, there is no set time limit for the development of the scale.

Also the student is given an answer sheet, indicating their choice; it presents the option of choice in four different modes for each of the scales.

At the end of the answer sheet, there are four boxes to enter a partial score and a box for a total score obtained by the sum of the parts. The answers obtained are multiplied by the value and these results are added, thus giving a score for each scale and if these are in addition to the four scales ($A + B + C + D$) it yields a total score.

In case the subject has not scored in answering questions, no value is assigned. This means that the four scales can be obtained: a total score of all items per scale and ~ all scales rated each of the strategies to be analyzed, identified by a ~ number of items partial scores according to the item selected.~

Procedure

We conducted a pilot test with students from fifth year of the career of Psychology. The results set the design of this study and test the instrument in evidence.

Design and Statistical Analysis

This is a non-experimental research; it is a descriptive correlational design with a transectional-correlation. In this design the data is taken in one moment, and its purpose is to describe variables and to analyze their interrelationships. The difference that is established with the other designs is that data collection is in an unique moment. In this regard it states: "This design aims to describe relationships between two or more variables at a time." (Hernández Sampieri, 1987: 194)

Dependent variable: The averages of the grades are the grades of students attending the fifth year of the career of psychology until the test. Independent variable: It is the total score obtained by pupils in the Scale of Learning Strategies, ACRA: Acquisition, Consolidation, Recovery and Support. (Gallego and Román, 1994)

RESULTS AND DISCUSSION

Analysis of the use of learning strategies

In order to investigate what strategies the students used, it was assumed that the overall averages are related to the strategies used. In order to obtain more precise conclusions the sample was divided into two groups: A and B students. A group of students, whose average is below the overall average grades, and group B, composed of students who are at or above average general notes. The overall average is 6.33.

This classification is very important for the purposes of this study to characterize and compare the two groups, thus making possible a more detailed and careful analysis. In group A is given the use of acquisition strategies, retention of information and repetition. The information is kept until you perform this task. In this way information is acquired by the sensory register and held in the STM by the use of these strategies. The internal process of repeating and reviewing the material allows the newly encoded information units that are maintained for longer periods of time.

The degree of use of strategies for acquiring and developing, lets say that the presentation of information in the schemes is to establish relationships between the external surface and prior knowledge and new information. The relations are fragmented, do not reflect or establish comparisons, similarities and differences between knowledge and learning and new information, or to own conceptualizations. If you just look again and again and again, the information is maintained in the CCM, but it does not necessarily go to the LTM. Therefore the resulting learning is limited. The knowledge obtained in this way is declarative. Students know the information, but the relationships built are related to conceptual material that works at the moment.

The B group of students used the tactics of classification, search for information, organization of the task with which students initiate processes that relate to enforcement, planning and evaluation at different levels of learning. In other words, their mode of study involves the use of support strategies, including the metacognitive and social ones. The use of these strategies ensures the implementation of complex psychological processes such as thinking, understanding and implementation of inferences from general theoretical principles, establishing relationships and personal interpretations of information, with changes and reorganizations within the same cognitive structure resulting from the addition of new content. These strategies are prevalent features of the CCM and LTM. The first involved in the processes of generalization and transfer of knowledge at this stage is the material received that must be met in order to work through processes of clustering, testing or development, to store later in the LTM.

The CCM, in its role of working memory, receives the material recovered from the LTM, compared with the new units of information, and recognizes, combines or integrates with the material received, in order to form new concepts. Then, that information is conveyed to the LTM and the depth of complex strategies and organizational development will certainly be recovered. The LTM system is involved in the storage of declarative knowledge, procedural and conditional schemes, as already explained in previous pages these procedures lead to an understanding of knowledge about things, how to do things, and knowledge about where and why to use them.

In short, the B group of students used the three types of knowledge and strategies that lead to significant, comprehensive and strategic learning. (Well, 1998; and Monereo Castelló, 2000)

In summary, the above analysis can affirm that the groups A and B use different learning strategies, so that there will also be different results in learning.

The results corroborate the hypothesis stated.

It was shown that the strategies used by both groups of students differ in the degree of complexity of cognitive processes and the role of memory systems and patterns of thought.

It was found that the cognitive processes used by students in group A were related, preferably with the acquisition of learning strategies, repetition and review, with coding strategies, particularly strategies of memorization. It was found that the internal process of repeating the material, allowing the newly encoded information units to be kept in the system and to form part of the knowledge structures. The information is stored in the MLP from the repetition and the use of memorization techniques. The knowledge gained in this way is saved to form the patterns and declarative knowledge.

It could be demonstrated that students in Group B used all strategies, but emphasized the choice of recovery strategies and support. Acquisition strategies enabled them to register and obtain information from the media, but from the strategies of development and organization, cognitive processes are activated that allowed complex information processing. In this way, the students organized and structured differently from traditional knowledge, establishing a system of relations between prior knowledge and new information incorporated into the system.

It was determined that knowledge and storage can be retrieved using searching strategies or generating response. Cognitive processes are used to relate the search for ideas and concepts that enable the acquisition of self awareness of the task to regulate the learning achieved, thus the proposed objectives may evaluate its effectiveness. It was found that

strategies used for reflection and understanding makes it possible to relate the knowledge stored. This intent on learning leads to the development of conditional or strategic knowledge, which refers to the awareness of knowing what, why and what strategies to use. This awareness offers students a degree of control over their learning process and the development of metacognitive knowledge.

The results indicate that the goals that guided the learning tasks are different in both groups. In group A they were directed to solve the task, resulting in the activity itself, but knowledge is limited to that offered by the material. The strategies used by students, preferably, were the acquisition and memorization that characterized as passive and dependent, both the task and the teacher's directions.

However, students in Group B used preferentially oriented strategies to regulate their own learning, seeking meaning to the task performed, and understanding in several stages of the learning process. This would include involvement in the task and the achievement of their aims. The student of this group was characterized by being active in the construction of meanings and independently of the particulars of the teacher in carrying out the task.

Students Group A

- 1) They Use a small number of learning strategies.
- 2) They have limited understanding of the strategies used to solve the learning situation.
- 3) The repertoire of strategies is limited in the selection process, control and monitoring of strategies used.
- 4) The intentions are directed exclusively to fulfill the task.

Students Group B

- 1) They use a wide range of learning strategies.
- 2) They understand when, where and why these strategies are important.
- 3) They select, supervise, monitor and evaluate the strategies used.
- 4) Their intentions are aimed to achieve success.

FINAL WORD

For all the above and agreeing with the work done, we can say that traditional teaching, which uses the accumulation of knowledge through strategies of acquisition, repetition and memorization must move towards a learning process aimed at encouraging the use of organizational strategies, preparation, reflection and understanding, i.e. coding strategies, recovery and support. Thus, encouraging the student to take responsibility and monitor their own learning. It seems, then, that to teach and to learn how to learn is the most important goal of education. Undoubtedly, one of the most important aspects of learning to learn means to encourage students to build tools to help them become aware of their learning process, the strategies used and that it is him who oversees and monitors the process of learning, which includes the possibility that the student reviews and verifies the causes of their difficulties, ultimately fostering metacognitive knowledge.

The formation of the student should then be directed to the construction of learning strategies that enable them to enter a complex and changing world, where they continually face many problems.

These findings are relevant for teachers of the School of Psychology, reflecting concern on their practices in respect to each subject, and to design actions to improve academic outcomes.

[...] Education is obliged to provide nautical charts for a complex world and in perpetual turmoil and at the same time, the compass in order to navigate it. (Unesco, 1999).

Addressees: This book is directed to teachers and pupils of all the educational levels, not only to the university students but it also offers a general frame for the study of the strategies and the importance of the education with a view on reflexive and significant learning. Outside this setting, it is directed to the Spanish-speaking countries, for the similar educational problematic, for the theoretical foundation that we share and for the applied technology of ACCRA that help to build learning strategies because its authors are Spanish, Roman and Galician.

Academic Institutions: To the educational institutions of all levels since it can be a text consulted by the pupils as well as by the teachers.

Channels of diffusion: From the checked bibliography one distinguishes that there is no registered book published by a publishing house that approaches the learning strategies at University. Given that the topic is of current interest and the educational problematic needs of a deep boarding and of all the actors that are involved in it.

Curriculum Vitae

Psychologist- Magister in Educational Psychology, National University of Tucumàn-. Regular Assistant teacher in Educational Psychology - Regular Assistant teacher in Cognitive Psychology. Assistant teacher in Problematic of the school living together. Faculty of Psychology, National University of Tucumàn . Researcher categorized by the Council of researches. Participation in different projects as researcher: school failure, top Education, learning strategies, school violence, disability. Member of scientific committee, head of thesis, commissions of evaluation. Expert member of disability, named by the Provincial Health System. Psychologist of the Disability board. Precedents: Chapters of the book:

“Analysis of the relation school - family opposite to the school failure” Co-author “The School Failure. Reconstruction of some processes...” Faculty of Psychology. UNT.

Authoress of the chapter: The approach of the Cognitive Psychology and his contributions to the learning. In Educational Psychology. UNT Manifestations of the violence in the relation between teachers and pupils Coautora in the book To learn to live Through Both " Problems of Learning: Un Interpretation ". Co-author. School, family and cultural diversity. Between the subordination and the cooperation Co-author. Article of the magazine Tests and Experiences. Editions Educational Innovations. Year 7 N ° 36. Noviembre/ December of Buenos Aires. Mexico.

The learning strategies in the construction of the knowledge in the Top Education Author.

REFERENCES

- Abate Of Tadeo, N. (1999): "The cognitive processes and the construction of scientific knowledge in the university classroom." In VI Conference on Research in psychology over the new millennium. School of Psychology. Ministry of Research. Research Institute. UBA.
- Bernard, J. A. (1992). "Estrategias de aprendizaje y enseñanza: evaluación de una actividad compartida en la escuela". En Monereo, C. (comp.): *Las estrategias de aprendizaje: procesos, contenidos e interacción*. Madrid: Domenech Ediciones..
- Brown, A.y Palincsar, A. S. (1989): "Guided, cooperative learning and individual knowledge acquisition" In L. Resnick (ed) *Knowing, learning and instruction*. Hillsdale, N.J. L. Erlbaum.
- Bruner, J., Goodnow, J. J. and Austin, G. A. (1958): *The acquisition of concepts*. Separata. Faculty of Arts. Tucumán. University Press.
- Bruner, J. (1990): *Acts of meaning. Beyond the cognitive revolution*. Madrid: Alianza Editorial. (1998): *Action, Thought and Language*. Madrid: Alianza.
- Carretero, M. (1997): *Introduction to Cognitive Psychology*. Buenos Aires: Aique.
- Carretero, M. and others (1998): *Processes of teaching and learning*. Buenos Aires: Aique.
- Carretero, M. & Pozo, J. I. and Asensio, M. (1989): *Teaching of Social Sciences*. Madrid: Visor.
- Castelló, M. and Monereo, C. (2000): "The conceptions of the teachers on the teaching of learning strategies." *Essays and Experiences in Review* No. 33. Concepts and practices in learning and teaching. Buenos Aires: Ediciones educational News.
- Coll, C. and Valls, E. (1992): "Learning and teaching procedures. In Coll, C., Pozo, J., Sarabia, B. and Valls, E.: *The contents in the reform. Teaching and learning concepts, procedures and attitudes*. Madrid: Santillana.
- Coll, C., Palacios, J. Marchesi, A. (comp) (1996): *Psychological Development and Education, II. Educational Psychology*. Madrid: Alianza Psicología.
- Cook, L. K. and Mayer, R.E. (1983): *Reading Training Strategies for Meaningful Learning from Prose*. As Pressley and Levin (Eds.) *Cognitive Strategy Research: Educational Applications*. New York: Academic Press.
- Corral, Z. and Alcalá, M. (2002): "Strategy learning and study of university students" in *Institute of Education Sciences - Faculty of Humanities*. UNNE. Resistance. Chaco. Argentina
- Craik, F. I. M. and Tulving, E. (1980): "Depth of processing and retention of words in episodic memory." *Studies in Psychology*. Madrid: Narcea.
- Chadwick, C. B. (1988): *Strategies of cognitive and affective learning*. " *Revista Latinoamericana de Psicología*. Venezuela.
- Dansereau, D. F. (1985): "A Learning Strategy Research." In J. V. Segal, S.F. Chipman, R. Glaser (eds.): *Thinking and learning skills. 1: Relating instruction to research*. Hillsdale: N. J. Erlbaum.
- Eduforum: Portal news. In: <http://www.eduforum.com.ar>.
- Edwards, D & Mercer, N. (1998): *The shared knowledge. Understanding in the classroom*. Barcelona: Paidós.
- Entwistle, N. (1988): *The understanding of learning in the classroom*. Barcelona: Paidós

- Estévez Nénninger, E. (2002): Teaching to learn. Cognitive strategies. Mexico: Paidós
- Flavell, J. H. (1985): The cognitive development. Madrid: Visor.
- Gaskins, I. and Elliot, T. (1999): How to teach cognitive strategies in school. The Benchmark manual for teachers. Buenos Aires: Paidós.
- Genovard, C. and Götzens, C. (1992): Psychology of Instruction Madrid: Santillana.
- Hernández Sampieri, J et al (1987): Research Methodology. Madrid: Mc Graw Hill.
- Jones, B. F. and others (2001): Strategies for teaching learning. Buenos Aires: Aique.
- Justice, F. and De La Fuente, J.: "Analysis of factorial ACRA Scales in a sample of university students." Mind and Behavior in The State of Education. Electronic Magazine of the Department of Psychology. Universidad de Valladolid 1999. Volume I. 1. Pages 41-50. 30/0872003 presentation online. [http:// www.uva.es / psychology / 01015166.htm](http://www.uva.es/psychology/01015166.htm).
- Kirby, J. (1984): Cognitive strategies and educational performance. New York: Academy Press.
- The Gazette (2002): Role of the University in times of crisis. Debate on the University days. Presentations by panelists participating. Editions of the National University of Tucumán.
- Litwin, E. (1997): The educational settings. Buenos Aires: Paidós.
- Mateos, M (2001): Metacognition and Education. Buenos Aires: Aique.
- Mayer, R. E. (1991): Thinking, problem solving and cognition. Barcelona: Paidós.
- Miller, G. A. (1956): "The magic number seven, plus or minus two: some limits on our capacity for processing information" Trad. Cast. Sebastian, E. (1983) Lectures on the psychology of memory. Madrid: Alianza Editorial.
- Monereo, C. (1990): "Strategies for learning in formal education: teaching and thinking about thinking" in Children and Learning Magazine. No. 50, 3-25
- Monereo FONT, C (comp) (1993): Strategies for teaching and learning. Process, content and interaction. Barcelona: Doménech.
- Monereo, C. (ed.) (1995): Strategies for teaching and learning. Teacher training and implementation at the school. Barcelona. Grao
- Navarro Guzmán, J. I. (ed.) (1993): Human Learning and Memory. Basic aspects and evolutionary. Madrid: Mc Graw Hill.
- Neisser, U. (1981): Cognitive Psychology. Mexico: Trillas.
- Nisbett, J. and Shucksmith, J. (1997): Learning Strategies. Madrid: Santillana / Aula XXI.
- Novak, J. D. and Gowin, D. B. (1988): Learning to learn. Barcelona: Martinez Roca.
- Paris, S., Lipson, M. and Wixon, K. (1983): "Becoming a strategic reader. Contemporary educational psychology. New York: Springer-Verlang.
- Pramling, I. (1993), "Metacognition and learning strategies." In C. Monereo (Ed.) Learning Strategies: Content and process interaction. Barcelona: Doménech.
- Pozo, J. (1996) cognitive theory of learning. Madrid: Morata.
- Pozo, J. I. (1998): Learners and teachers. Madrid: Alianza Editorial.
- Pozo, J. I. and Monereo, C. (1999): The strategic learning: learning to learn from the curriculum. Madrid: Santillana.
- Pozo, J. and Postigo, Y. (2000): The procedures contained as schoolchildren. Barcelona: Edebé.
- Puiggrós, A. (1993): University, project generation and pedagogical imaginary. Buenos Aires: Paidós.
- Resnick and Beck (1986): Education and learning to think. Washington D.C. Springer-Verlang.

- Rigney, J. W. (1985): "Learning Skills: A Theoretical Approach." In Segal, Chipman and Glaser (Eds.): Thinking and Learning Skills. Hillsdale. N.J.
- Riviere, A (1987): The subject of cognitive psychology. Madrid: Alianza.
- (1991): Objects mind. Madrid: Alianza Editorial.
- Roman, J. and Gallego, R. (1994): Scale of learning strategies: acquisition of information, encoding information, information retrieval and processing support. ACRA Madrid: Ediciones TEA.
- Sabater, F. (1997): The value of education. Argentina: Editorial Espasa Calpe.
- Schmeck, R. (1991): Learning strategies and learning styles. New York: Plenum. Press.
- Sierra, B. and highways, M. (1996): "Learning, Memory and Information Processing: Cognitive Psychology of Instruction" Cap. 8. In Coll, C, Palacios, J. and Marchesi, A. (ed) Psychological Development and Education II. Madrid: Alianza Psicología.
- Stenhouse, L. (1987): The research base of teaching. Madrid: Morata.
- Unesco (1999): The Treasure. International Commission on Education for the Twenty-first Century chaired Jacques Delors. Madrid: Aula XXI Santillana
- Valls, E. (1993): Proceedings: learning, teaching and assessment. Barcelona: ICE / Horsori.
- Vasilachis of Gialdino, I. (1992): Quantitative Methods I. The theoretical and epistemological problems. Buenos Aires: Centro Editor America Latina.
- Vega, M. de (1990): Introduction to Cognitive Psychology. Madrid: Alianza Psicología.
- Weinstein, C. E. and Mayer, R. E. (1986): The teaching of learning strategies. In M. C, Wittrock (ed.): Handbook of research on teaching. New York: MacMillan.

Chapter 8

COGNITIVE REHABILITATION IN MIDDLE-AGED ALZHEIMER PATIENTS

Elisabetta Farina and Fabiana Villanelli

Neurorehabilitation Unit, IRCCS Don Gnocchi Foundation,
University of Milan, Milan, Italy

INTRODUCTION

General Principles of Cognitive Rehabilitation Treatment of Middle-Aged AD Patients

Literature data support the notion that Alzheimer Disease (AD) patients show some sort of cognitive reserve capacity that can be exploited in cognitive training. In fact, recently some randomized controlled trial have demonstrated the efficacy of cognitive stimulation treatments in order to improve cognitive status and quality of life in people affected by dementia (Spector, 2003; Olazaran, 2004). On the other hand, in AD clinical heterogeneity is the rule, not the exception, and the disease is invariably progressive. For these reasons, cognitive rehabilitation interventions must be accurately tailored to the clinical characteristics of the patients. It must also be considered that AD affects family as well as the patient, and these interventions must take into account the needs of both patients and caregivers. Interventions must try to reduce disability, preserving residual cognitive, affective and physic abilities as long as possible. A multidimensional evaluation, taking into account residual cognitive and functional abilities, the possible presence of psychobehavioural disturbances, of associated general illnesses, and of the familiar and social support is necessary to establish reasonable goals for the cognitive rehabilitation program. This evaluation should include:

1. A complete battery of neuropsychological tests, covering all main cognitive functions (short and long term memory) better if tests of “ecological” memory are included, such as the Rivermead Behavioral Test, (Wilson et al., 1990), semantic memory, language comprehension and production, visuospatial and visuooperative functions, constructive and ideomotor praxia;

2. Scales to evaluate psychobehavioural disturbances, e.g. the Neuropsychiatric Inventory (Cummings et al, 1994) or the Revised Memory and Behaviour Checklist (Teri et al., 1992), and depression (e.g., the Geriatric Depression Scale) (Yesavage et al. 1982-83) or the Cornell Depression Scale for Dementia (Alexopoulos et al, 1988);
3. Tools to evaluate functional disability. Traditional “generic” functional scales, such as ADL and IADL (Lawton et al, 1969) are insensitive to the large variety of impairment shown by middle-aged AD patients in everyday life, and they do not reflect adequately the kind and the amount of help that is needed for cognitively impaired persons to plan and perform an action, a variable that can be modified by treatment. Therefore we recommend the use of more sensitive tools, such as the Alzheimer's Disease Activities of Daily Living International Scale (ADL-IS), that covers a large sample of activities of daily living, and shows high correlations with measures of cognitive functions and stage of dementia (Reisberg et al., 2001). A good option may be the use of performance measures of functional abilities: these are tools in which an individual is asked to perform or simulate an activity and is evaluated in a formal manner on that performance with standardized criteria. They have been used in medical rehabilitation for diagnosis and to demonstrate therapeutic progress, and have shown to predict survival, hospitalization, use of assistance, long-term-care and nursing home placement (Kuriansky and Gurland, 1976; Jette and Branch, 1985, Williams, 1987; Guralnik et al., 1989; Reuben et al., 1992). Other claimed advantages are good patient's acceptability, and good interrater reliability (Guralnik, et al., 1989; Reuben and Siu 1990; Mahurin et al., 1991). An example of performance measure is the Direct Assessment of Functional Status (DAFS, Lowenstein et al., 1989): the DAFS features mainly IADL skills (communication abilities, transportation, financial skills, shopping skills), along with two BADL skills (eating and dressing/grooming skills), and time orientation. Performance is rated as correct or incorrect. Our group has recently standardized another performance measure, The Functional Living Skills Assessment (FLSA) focused on mild ambulatory AD patients, which explores 8 areas of interest (Resources, Consumer Skills, Public Transportation, Time Management, Leisure, Telephone Skills, Self-Care and Health) and assesses a large range of functions, allows us to follow the patient evolution in an analytical manner (but it also provides a total score, that it easy to calculate and to follow serially) (Farina et., 1999; Farina et al., submitted). In two studies about cognitive rehabilitation in dementia, we demonstrated that the FLSA was the most sensitive instrument to detect functional changes in AD patients after performing a cognitive training of a 5-week duration (Farina et al., 2002; Farina et al., 2006 a)
4. Specific scales to evaluate comorbidities (even if they are less often present in middle-aged AD patients than in older ones) e.g. the CIRS (Parmalee PA et al 1995).
5. Tools to assess the impact of providing care to AD patients on family members' life, such as the Caregiver Burden Inventory (CBI, Novak et al., 1980), and to detect depressive symptoms in caregivers (e.g. Beck Depression Scale, Beck et al., 1961).

New diagnostic criteria for dementia consider not tenable the distinction between presenile and senile dementia (Reisberg, 2006), and even if some studies about the epidemiology of AD have claimed the younger AD patients have a disease evolution more

rapid than the oldest, these data have been denied by other studies (with the exception of genetic dominant forms- Reisberg et al, 1989-). On the other hand, the clinical impression and the problems shown by middle aged AD patients in clinical practice are really different from older patients: a temporary stabilization of the cognitive status after starting a treatment with cholinesterase inhibitors is rarer than in older patients, the evolution of the disease is usually rather quick, and atypical forms of AD (e.g. with early and or relatively selective involvement of language or visuo-perceptive functions) are frequently seen. This raises the possibility that the patient might be affected by other dementias (above all dementias of the frontotemporal spectrum). Middle-aged AD patients are also different as far as cognitive rehabilitation or stimulation is concerned.

In our practical experience of several years, we rarely saw clear improvement at neuropsychological tests or in functional tasks of middle-aged AD patients treated with cognitive rehabilitation or stimulation. On the contrary, this was the case for a good percentage of older patients recruited in our studies (Farina et al., 2006 a e b). Mostly middle-aged patients seem to follow a steady slope of deterioration, with almost every technique used (training of functions relatively conserved in the first phase of the disease, both with paper-and pencil and with computerized tasks; use of external aids or devices; training of the procedural memory in the activities of daily living; training with techniques based on implicit memory, such as errorless learning, spaced retrieval and forward or backward cueing. For most patients, cognitive-oriented techniques must be abandoned relatively quickly for more “generic” and simpler methods, such as occupational and recreational activities, which can give some results, more as far as behavioral problems are concerned rather than from the cognitive or functional point of view. To this aim, the choice of occupational/recreational activities must be accurately tailored on the past occupations and on the preference of the patient. It is necessary to question the patient, the spouse and/or other relatives about that, grading the degree of satisfaction that the patient seemed to find in a certain activity, and how frequently and from how long the patient practiced the activity. It is also necessary to test whether the patient is still able to perform the chosen activity without aid, or with minor aid. These are patients that are cruelly struck by the disease while still working and living a life with plenty of things to do and with social contacts. They rapidly lose their social and financial status, must retire from work and driving (not always voluntarily) and are often obliged to live a retired life at home (families of middle-aged dementia patients are usually shamed to show the patients to previous neighbors and friends). Therefore, they are easily frustrated if they realize that are no longer able to perform occupational activities, which would have been very easy for them before the disease started.

It has been underlined that collaboration with the patient’s family is an important part of the rehabilitation program: younger AD patients are different from the older ones also from this point of view, e.g. for the possible presence in the family of children in their teens (and even in their childhood), or in any case too young in order to understand the disease and accept it. Psychological intervention extended to all the family (patient, spouse, children, and others) can be particularly important in middle-aged patients. Performing sessions in the clinical setting does not exhaust the whole rehabilitation program: on the contrary, it is the point of departure for activities that, once planned during the sessions at the hospital, must be implemented and continued at home with the aid of the family. To this aim, familiar persons must be instructed relative to the specific techniques used in this kind of patient (e.g. errorless learning and forward cueing) and psychologically supported in order to face and manage

possible difficulties that can take place during the home sessions: e.g. the excessive confidence between the patient and his/her caregiver may reduce the patient's compliance and cause irritability: in this case the time of each home session must be reduced: sessions for collaborating patients may be 30-45 minutes long, while in the case of reduced compliance they must be 20 minutes maximum. The family collaboration with the rehabilitation program is essential from other points of view: the family must motivate the patient to take part in the hospital sessions and must assure a regular frequency; relatives must favor the birth of a therapeutic alliance between the patient, his/her family and therapists; they must stimulate the patient to generalize learning obtained in rehabilitation sessions to daily life.

Group intervention of cognitive stimulation can be particularly indicated in AD patients because it allow socialization, which has a positive effect on mood; however, AD is not common in middle age, and it is difficult to form groups. Therefore, in most cases patients receive rehabilitation in individualized sessions, or in groups formed by a very few patients (2-3), at least in our center.

DIFFERENT TECHNIQUES IN COGNITIVE REHABILITATION

In the following paragraph, we will give some details about the different techniques that can be used with patients affected by dementia.

In the first stage of AD, "specific" techniques, favoring relearning (or new learning) of a limited amount of information (e.g. the association face-name) can be proposed, such as spaced retrieval, the method of vanishing cues and errorless learning. These methods have been originally proposed as focusing on implicit memory, a type of memory preserved in early AD.

With the *spaced retrieval* technique, the patient is asked to retain an object that is presented at very short (few seconds) but increasingly longer intervals (5, 10, 20, 40, 60, 90, 120'' etc.). Intervals are filled with interfering tasks (such as a conversation). When the patient is unable to recall an item (for example after a 120 s interval), he/she receives a feedback and the retention interval is shortened to the previous step when the patient managed to recall a piece of information (90 s in this case). Spaced retrieval has shown its effectiveness in allowing AD patients to retain face-name associations (Camp and Foss, 1997), to localize objects (Bird and Kinsella, 1996) and to carry out prospective memory-related tasks (Mc Kitrick et al., 1992; Kixmiller 2002). Clare et al. (1999, 2000, 2002) administered spaced retrieval, in association with errorless learning and vanishing cues, to some AD patients who had to retain ecologically relevant face-name associations or personal information (see later on). Another implicit memory-oriented learning approach is the method of *vanishing cues* (previously successfully administered to amnesics): the patient is required to retrieve a verbal piece of information and he receives all the letters (cues) he needs to meet this goal. There are two different procedures: patient is asked to spontaneously retrieve a verbal piece of information (for example the name of a person). If he/she does not recall it, he/she is provided with an increasing number of letters to get the right word until the patient manages to retrieve it ("forward cueing"). At the second step, the patient is provided with a number of letters equal to the letters he previously needed to retrieve the item, but one less, and so on. The alternative procedure ("backward chaining"), initially provides the patient with all the letters

composing a to be recalled item. The letters are then progressively decreased according to the patient's ability to retain the piece of information. The method of vanishing cues has shown to be effective in teaching AD patients face-name associations (Van der Linden and Juillerat, 1998), addresses and telephone numbers (De Vreese, 1999). Bird et al. (1995) managed to reduce behavioral disturbances in some demented patients by combining spaced retrieval with the method of vanishing cues. The studies of Clare et al. (1999, 2000, 2002) have been already mentioned.

Errorless learning has been derived by studies on amnesic subjects and focus on minimizing the number of errors during the learning process. This technique appears to be more beneficial in improving the ability of patients with explicit memory impairment to acquire new pieces of information than the errorful learning method. According to Wilson and Evans (1996), errorless learning improves learning by relying on implicit memory, which is very likely to be affected by errors, as it is perseverative and poorly flexible. Clare et al. (1999) successfully administered the errorless learning technique to a mild AD patient who had to learn 11 face-name associations concerning her club companions. However in this study, the errorless learning technique was combined with a language processing strategy, and with the vanishing cues spaced retrieval methods. The same authors (Clare et al., 2000) have then presented, together with the previous study, the results they obtained by administering the same combination of procedures to other 2 subjects. In this case, the patients were successfully trained to learn face-name associations or personal information. Another patient was trained to learn face-name associations of well-known people by using the errorless learning principle in association with one of the other techniques at a time. In the same article, the authors also administered the errorless learning technique to teach the use of external aids (calendar, diary, black board) to two AD patients in order to reduce the number of their repetitive questions (see later on).

However, in spite of these promising premises, more recent studies have questioned the usefulness of errorless learning in patients with dementia (Dunn and Clare, 2007; Haslam et al., 2006; Metzler-Baddeley and Snowden, 2005). From these studies, it seems that advantages of the errorless learning technique are limited (e.g., it can be useful to learn general information rather than specific ones), and that only some patients can benefit from it. Moreover, if the patient has still a residual of explicit memory, he/she will learn more throughout this residual than by using implicit memory.

It must also be recognized that most studies focusing on spaced retrieval, vanishing cues and errorless learning are small and there is poor evidence of a generalization in daily living tasks. More, it can be difficult to determine what kind of information may be useful to (re)learn for AD patients in everyday life, and the errorless learning technique can be difficult to use with some patients to their impulsiveness.

Another possibility with AD patients in the first stage is the use of external aids and supports, such as alarm clocks, place cards, diaries, boards, colored posters, and electronic aids. However, available data on this subject are limited, and further investigation is necessary.

Bourgeois et al. (1997) obtained a reduction of repetitive questions in a group of mild to moderate AD patients thanks to the use of a "memory book" they produced with the caregiver's help and containing family pictures, a checklist of daily living activities and drawings of to be done activities with time schedule. Also Clare et al. (2000) obtained a reduction of repetitive questions by using external aids (calendar, diary, board) with two

mildly affected AD patients and administering errorless learning. However, only one patient did not lose the improvement at the follow up. Zanetti et al. (2000) trained 5 mild to moderate AD patients to learn 7 ecologic prospective memory-related tasks by the means of an electronic diary. The results produced by the use of the electronic diary were then compared with two control conditions (free retrieval following “spontaneous” learning and retrieval supported by a written list of cues). Patients performed significantly better in the first case than in the control conditions.

The most important prerequisite of studies on external aids is that thanks to the use of environmental supports, the to be done activity becomes less episodic and semantic memory dependent (the two compromised memories) and more procedural memory dependent. For example, by combining the use of big boards showing the name of given objects or places with oral instructions and practical demonstrations, it is possible to improve patients’ performances in instrumental activities of daily living such as preparing breakfast, a coffee and so on.

Patients must be motivated to use external aids in their activities of daily living until they become part of their daily routine and increase their independence. For this reason, this intervention must be individually tailored and the method that encourages the patient to use aids must be carefully studied and administered (for example by dividing the learning process into different steps, by detecting the most effective way to elicit the appropriate reaction, by using errorless learning).

Very recently, preliminary data indicate that patients with Alzheimer disease can benefit also from the stimulation of “residual” neuropsychological functions carried out through *computerized programs* (Cipriani et al., 2005). In a pilot study, Tàrraga and coworkers (2006) compared an experimental group of AD patients, treated with a multimedia internet-based system (Smartbrain) and an integrated psychostimulation program, and two control groups, the first treated only with the psychostimulation program, and the second one not submitted to cognitive stimulation. Both groups received acetylcholinesterase inhibitors. After 12 weeks of treatment, the experimental group improved in two measures of cognitive global function (MMSE and ADAS-Cog), and this improvement was maintained at the follow-up. Another recent study, including patients with AD and with MCI (Talassi et al., 2007) compared a rehabilitation program including a computerized training along with a more generic and global approach, and a program including only the last one.

Both MCI and AD patients improved with the program including also the computerized approach from the cognitive and psychiatric point of view. AD patients treated only with the global approach showed minor cognitive improvement.

In the mild to moderate phase of dementia, more “global” and less specific interventions must be proposed.

Reality Orientation Therapy is the most known cognitive stimulation technique in AD, developed in the 50’s and then improved during the following ten years (Taulbee and Folsom, 1966).

It is a technique that, through a focused and continuous stimulation, helps the patient to reorient himself/herself towards the environment: this leads the patient to a better comprehension of what surrounds him improving his/her sense of control and self-esteem. The theoretical foundations of the ROT are multiple. However, all the authors seem to agree in founding the rehabilitation process on the stimulation of the parts still partially integral of

the individual mental state, with the aim to develop some form of independence (Brook, 1975; Florenzano, 1988).

There are two forms of ROT: formal ROT and informal ROT. Informal ROT approach is double: it involves a reorganization of the environment by the means of aids, such as calendars, clocks, signs (indicating toilets, kitchen etc.) and a repetitive reality reorientation through direct stimulation. The staff throughout the day carries out these activities in order to let patients recall basic information such as present day, month, year, age, location etc. Formal ROT is a structured group therapy. Formal ROT group sessions (composed by a maximum of five people at the same involuntal stage) take place in a room built as a common house, and equipped with a big clock, a calendar and a black board; they usually last one-hour maximum. The first part of the session is devoted to acclimatization following the daily space-time orientation criteria (present day, month, year and location), while during the second part some exercises are proposed (dealing with space, time and personal orientation).

According to literature, ROT has been found to improve verbal orientation and memory for personal facts; other studies have reported slight improvements also in other cognitive measures, behavior and social interaction. However, it is uncertain whether ROT produces a positive impact on daily living activities and what is the persistence of its effects.

In last the 20 years, various researches have analyzed ROT efficacy in AD. The metanalysis carried out from the Cochrane Collaboration (Spector et al., 2000) has concluded that there is a sure evidence of effectiveness both for cognitive and behavioral aspects (even if the positive effect seems of short duration); the author thinks therefore that the ROT would have to be considered like part of the treatment of people with dementia. A recent controlled randomized multicentric study (Spector et al., 2003) in which patients received a treatment inspired mainly to the ROT and to the cognitive stimulation has confirmed the possible benefits for the patients affected by dementia, who in this study improved regarding to controls in several parameters (MMSE, ADAS-Cog, Quality of life-Alzheimer' s Disease scales). Authors have calculated that the amplitude of the improvement was substantially comparable to those obtainable with inhibitors of cholinesterase in clinic trials. Unfortunately, the effect does not last a long time. However, there is some evidence that a program supported in the time can maintain the advantages acquired (Orrell et al., 2005). A retrospective study has concluded that the application of repeated cycles of ROT during initial and intermediate stages of disease could delay the cognitive decline and institutionalization (Metitieri et al., 2001).

ROT appears effective also when administered by a caregiver trained to offer the program at home (Onder et al., 2005).

Reality orientation enhances the effects of donepezil on cognition in Alzheimer's disease. ROT approach is often combined with two emotion-oriented techniques (Ishizahi et al., 2002; Onor et al., 2007): Reminiscence Therapy and Remotivation Therapy. They are, in fact, called 3R therapies.

The *Reminiscence* technique aims to bring into consciousness past experiences and unresolved conflicts, thus helping elderly people to put their experiences into perspective and preparing for death (Head et al., 1990; Burside and Haight, 1994). The idea is that, since remote memory is usually the last to deteriorate, RT could be an effective means of communication for demented patients. This therapy usually involves group meetings, in which participants are encouraged to talk about past events (e.g., aspects from their childhood, love relationships and marriage, education and work life, anniversaries and

celebrations of historic events); they are often assisted with aids such as music or objects associated with those events in order to stimulate memory and mood. According to the Cochrane Review, the randomized (or almost randomized) trials that have been carried out on this subject (Baines et al., 1987; Goldwasser et al., 1987; Orten et al., 1989) are not sufficient to reach any conclusions on the efficacy of the Reminiscence Therapy, although the best trial (Baines et al., 1987) reports a slight but statistically insignificant improvement in behavior. (Spector et al., 1999). A more general literature review on emotion-oriented approaches in the care for persons suffering from dementia concluded that mainly positive results (including increased social interaction and decrease of behavior problems) are achieved with these kinds of approaches. Unfortunately many studies have methodological limitations and are done independently, which makes comparison difficult (Finnema et al., 2000).

The *Remotivation Therapy* was initially developed to treat schizophrenic patients but was then administered also to institutionalized elderly patients with psychogeriatric problems (Abrahams et al., 1979; Levy, 1987). The therapist aims to mobilize patient's interest in his environment by stimulating him every day, individually or in a group session, and leading him to focus his attention on simple subjects and/or events (history, holidays, food, money etc.). Unlike what happens in psychotherapy sessions, subjects concerning emotional problems such as the relationship with the family, diseases, institutionalization, religion and so on, are avoided as much as possible. The Remotivation therapy involves a highly structured method in its group sessions. However, the studies about the effectiveness of this technique in patients with dementia are scanty. Janseen and Giberson (1988) outlined that after a Remotivation therapy training, patients affected by various degrees of dementia showed a greater interest in group activities and an increased verbal and emotional communication level.

With the progression of dementia, treatments with *recreational activities*, such as games and art therapies (e.g., music, dance, art), that are frequently offered to people with dementia in nursing homes or day-care centers, can be useful to ameliorate mood and avoid social isolation of people with dementia. As discussed above, this kind of treatments can be particularly useful in the practical management of middle-aged AD patients. The primary purposes of recreational activities, according to the American Therapeutic Recreation Association (ATRA) guidelines, are to restore, remediate or rehabilitate in order to improve functioning and independence as well as reduce (or eliminate) the effect of illness or disability. Activity is a basic human need expressed in leisure and work pursuits; unfortunately, dementia leads to boredom and isolation due to a low rate of activity participation, and this results in agitated or passive behaviors, and in functional loss. Recreational Services are thought to provide recreation resources and opportunities in order to improve patients' health and well being (Fitzsimmons, 2003). Chosen interventions of recreational activities for AD patients must match the functional skills of the persons with dementia and their personality style of interest to provide stimulation and enrichment to the patient and thus mobilize the patient's available cognitive resources. However, only a few controlled studies have been performed to demonstrate efficacy of recreational activities in AD: there is some evidence that these interventions decrease behavioral problems, improve mood and increase socialization (Karlsson et al., 1988; Gerber et al., 1991; Rovner et al., 1996). Recently, it has been suggested that even some extremely easy activities, such as Bingo, can significantly improve cognitive performances in AD patients (unlike motor activity) (Sobel, 2001) Additional support for this recreational approach in AD treatment

comes from the works of Teri and Logsdon (Teri et al., 1992; Teri, 1994), who have developed a protocol that includes behavior psychotherapy and a number of interventions aimed at increasing the number of pleasant activities. This protocol has shown to improve the mood of patients and caregivers alike.

Recreational activities can be combined with occupational interventions: some data suggest a positive effect on functional abilities of demented patients by programs based on procedural learning (Zanetti et al., 1997, 2001): a significant reduction of time spent to perform selected activities of daily living was noted. On the other hand, educating caregivers about the impact of the environment on dementia-related behaviors, and about the relationship between excess stimulation and behavioral disturbances, has been shown to slow functional decline and to reduce behavior problems in a randomized, controlled trial (Gitlin et al., 2001). In another study, a brief structured intervention at home by an occupational therapist (suggesting adaptation of the environment, and strategies for control of reactive behaviors and improvement of residual functional abilities), and by a psychologist (giving psychological support to caregivers, and giving advice on family relationships, psychological consequences of caring and verbal and non-verbal communication) led to a significant reduction of the frequency of problem behavior and, to a lesser extent, of time spent for caring (Nobili et al., 2004). Adherence to occupational therapy recommendations can improve quality of life of AD patients living in the community and diminish caregiver burden (Dooley and Hinojosa J, 2004).

Our group has recently demonstrated cognitive and functional gains in demented patients treated with training of activities of daily living (based on stimulation of procedural memory) or recreational-occupational activities (plus support psychotherapy for patients and caregivers Farina et al., 2002, 2006 a). Patients treated with recreational-occupational activities also showed a significant improvement in behavior. A limitation of our studies was that in both cases we compared mentioned techniques to other non-pharmacological treatments; therefore, we had no control (not-treated) group. Therefore, we performed an additional aimed to overcome this limitation, by comparing a control group (AD subjects receiving only standard medical care) with AD patients taking part to a stimulation program based on recreational and occupational activities, associated to a brief cycle of support psychotherapy for patients and caregivers. When comparing baseline with post-training condition, patients displayed a substantial reduction in disruptive behavior, and a tendency to a general reduction of behavioral symptoms compared to controls. This reduction was mirrored by a significant reduction of caregiver reaction to behavioral disturbances (Farina et al., 2006 b).

Patients in the moderate to severe phase of dementia can benefit of *music therapy*, even if this kind of treatment has been proposed also in the early phases of the disease. Music therapy is a potential non-pharmacological treatment for the behavioral and psychological symptoms of dementia. It is, in fact, a safe and effective method for treating agitation and anxiety in moderately severe and severe AD. This is in line with the result of some studies on music therapy in dementia (Sherratt et al., 2004; Svansdottir HB et al 2006), even if a recent Cochrane report concluded that more and better quality research is required to investigate the effectiveness of music therapy in reducing problems in behavioral, social, emotional and cognitive domains in patients with dementia (Vink et al., 2004). But the effect of music therapy could not be limited to reduction of agitation and anxiety: a randomized placebo-controlled trial with blinded observer rater aimed to explore whether music, live or pre-recorded, is effective in the treatment of apathy in subjects with moderate to severe dementia,

concluded that live interactive music has immediate and positive engagement effects in dementia subjects with apathy, regardless of the severity of their dementia, while pre-recorded music is non-harmful but less clearly beneficial (Holmes et al., 2006).

Other studies have claimed that music could enhance cognitive performances of AD patients (Van de Winkel et al., 2004). In a recent study considerable improvement was found as far as autobiographical memory is concerned in the music condition, associated with a significant reduction in state anxiety, suggesting anxiety reduction as a potential mechanism underlying the enhancing effect of music on autobiographical memory recall (Irish et al., 2006).

For patients with severe dementia, *Validation Therapy* (VT), which was developed by Naomi Feil (1993, 1996) between 1963 and 1980 to offer an alternative to ROT and particularly for older demented patients living in care retirement communities, is frequently proposed as non-pharmacological treatment. Feil describes VT as a method to encourage the intellectual development in elderly people with mild or severe orientation disorders, that is aimed at restoring patients' self-esteem, reducing stress, anxiety and isolation from the external world, decreasing the need of safety measures, promoting contacts with other people, facilitating their independence and helping them to carry out unsolved vital tasks. According to the author, when more recent memory fails, elderly people try to restore balance to their life by retrieving earlier memories. Painful feelings that are expressed and "validated" by a trusted listener will diminish, while painful feelings that are ignored will gain strength, leading the elderly individual to social isolation and vegetative state. Feil classifies individuals with cognitive impairment as having one of four stages of a continuum of dementia: Malorientation, Time Confusion, Repetitive Motion and Vegetation. Each stage is identified by sets of both cognitive and behavioral characteristics: through the empathic listening, eye and physical contact, the therapist tries to understand the patient's point of view to establish an emotional contact with him or her; the goal is not to reach awareness of reality but to understand the meaning of the patient's behavior. The therapist of Validation accepts that a confused old man retires into his shell as a consequence of aging, and accepts his going back to the past as a survival mean, and a healthy process that lessens the age-related burden. In this way, the therapist "validates" the elderly individual's feelings and uses the empathy to be on the same wavelength with his interior reality. VT can be administered to the single patient, but whenever possible, it involves group meetings.

Various observational studies have indicated that there are positive effects in using VT with regard to the interactions that patients are able to make during validation groups (Bleathman and Morton, 1988; Babins et al., 1988). However, although the Cochrane Collaboration review has identified 18 studies on the efficacy of this technique, only two of them were randomized controlled trials (Robb et al., 1986; Toseland et al., 1997); these studies indicate that there is no statistically significant benefit but only a positive trend of Validation Therapy concerning some outcomes; in addition, the potential advantage of this therapy could depend only on a greater attention to the patient (Neal and Briggs, 1999).

Multisensory environments such as *Snoezelen*® rooms are becoming increasingly popular in health care facilities for individuals with moderate-severe dementia. *Snoezelen*® provides sensory stimuli to stimulate the primary senses of sight, hearing, touch, taste and smell, through the use of lighting effects, tactile surfaces, meditative music and the odor of relaxing essential oils (Pinkney 1997). The clinical application of *snoezelen* has been extended from the field of learning disability to dementia care over the past decade. The rationale for its use

lies in providing a sensory environment that places fewer demands on intellectual abilities but capitalizes on the residual sensorimotor abilities of people with dementia (e.g. Hope 1998). Some encouraging results have been documented in the area of promoting adaptive behaviors (e.g. Baker et al 2001, Long 1992, Spaul 1998), reducing agitation (Baillon et al., 2004), or apathy (Verkaik et al., 2005). However, the clinical application of Snoezelen® often varies in form, nature, principles and procedures. Such variations not only make examination of the therapeutic values of Snoezelen® difficult, but also make difficult the clinical development of Snoezelen® in dementia care. A Cochrane review of evidence for the efficacy of Snoezelen® in the care of people with dementia concluded that data were too limited to reach a firm conclusion (Chung et al., 2002) A crossover randomised controlled study aimed to evaluate the effect of Snoezelen® on the mood and behavior of patients with dementia, in comparison to Reminiscence Therapy concluded that both interventions had a positive effect (Baillon et al., 2004)

Gentle Care® is a prosthetic life care system developed by Moyra Jones (1996). The aim of this system is to help families and professional carers in understanding the diseases that cause dementia, thus allowing caregivers to develop a "prosthesis of care" based on the premise of carefully defining the deficit the person is experiencing: this "prosthesis of care" will seek to arrange an environmental fit between the person with dementing illness and the physical space, the programs, and the significant people with whom the person must interact. The Gentle Care® system accommodates and supports existing levels of function and development, rather than challenging the person with dementia to adapt and perform in ways no longer possible. Carers are assisted to evaluate the functional deficits and strengths of the client, they are provided with problem solving strategies, and they are taught to integrate daily activities with programs that exploit the patient's residual abilities (Vitali, 2004). The physical space must assure security, mobility, easiness of access, privacy, comfort, and socialization; it must suggest to the patient its own function, and it must be flexible to adapt to patient and carer changes. Meaningful activities, that aim to satisfy fundamental psychological needs, are integrated to build a daily routine, specific for each patient (according to his/her moral and cultural background, attitude, capability).

Finally, it deserves a mention the positive effects that *physical activity* and exercise can have in patients with dementia. In the last years, many data have accumulated on this point. Exercise training combined with teaching caregivers behavioral management techniques improved physical health and depression in patients with Alzheimer disease in a randomized controlled trial (Teri et al., 2003). A recent work, comparing supervised walking, comprehensive exercise (walking plus strength training, balance, and flexibility exercises), and social conversation (casual rather than therapeutic themes) found that participants receiving comprehensive exercise exhibited higher positive and lower negative affect and mood. (Williams and Tappen, 2007). In another study, a simple exercise program, 1 hour twice a week, led to significantly slower decline in ADL score in patients with AD living in a nursing home than routine medical care (Rolland et al., 2007).

A recent review suggests that literature supports the claim that physical activity enhances cognitive and brain function, and protects against the development of neurodegenerative diseases (Kramer and Erickson, 2007)

Another article reports the effects of language-enriched physical fitness interventions provided by university undergraduate students to 24 mild- to moderate-stage Alzheimer's disease patients. Socialization experiences consisted of supervised volunteer work and

cultural/recreational activities. Changes in global functioning and neuropsychological test performance were evaluated and compared to those of a similar group of untreated patients from the Consortium for the Establishment of a Registry for Alzheimer's Disease (CERAD). Cohorts completing 4 semesters or longer showed no significant between-year changes after their first year on the Clinical Dementia Rating, a measure of global functioning, and on 5 or 6 of the cognitive and language measures. Comparisons with the CERAD sample suggested a slower rate of decline for the AD treated group. The stabilization of global and cognitive performance was not apparent among participants who completed only 2 semesters. (Arkin 2007) Exercise sessions consisted of flexibility, balance, aerobic, and weight resistance activities. Highly significant fitness gains were achieved in the six-minute walk test, upper and lower body strength, and duration of aerobic exercise (Arkin, 2003).

This work is also notable for other reasons: it is an example of the most recent tendency in the literature about cognitive rehabilitation in AD, that is the combination of interventions of different nature (global/aspecific interventions are associated to selective/specific training): another example is a randomized study on AD and Mild Cognitive Impairment patients comparing a psychomotor intervention associating spatial-temporal reorientation, ADL training, socialization, and specific cognitive exercises (to train attention, language, visuospatial abilities, calculation, and frontal functions) with psychosocial intervention alone, and showing that the experimental group appears cognitively stable after six months, and less depressed after twelve months (Olazarán et al., 2004)

Arkin (2007) comments in this manner why she chose to perform a combined intervention (page 73): “Clinically, there is much to said for leaving the combined intervention intact. By offering a variety of activities, you are providing multiple and different opportunities for participants to be successful. Someone whose language skills are seriously compromised and resist improvement can still achieve pleasure and satisfaction from rocking babies at a day care center and/or make tangible and esteem-building gains in speed or duration of aerobic activity or increases in amounts of weight lifted. A frail individual who cannot do well on the physical activities may benefit from the cognitive activities and be able to read stories to preschoolers or newspapers to a blind person”.

Another reason for which the Arkin's work is interesting is that she included in her study two middle-aged AD patients. A 59 years old patient completed 4 years of treatment, thus entering in a small (4 persons) group showing stabilization in language measures, and less marked decline than CERAD controls at MMSE. On the whole, however, it is very difficult to extract information about middle-aged patients in the existing literature about cognitive rehabilitation in AD: no work specifically mentions these patients.

CONCLUSION

A Clinical Experience

In our clinical experience, it is difficult to initiate middle-aged patients to “classical” group training, because of the age difference with most AD patients (they do not have the same social and cultural background as elderly patients). Therefore, these patients are often treated with individual rehabilitation sessions. We want to detail, however, an experience in

which two patients, both of them age 58 at the beginning of training, were treated together twice a week for 40 sessions.

The objectives of the program and techniques used to attain these objectives were the following:

- Controlling the progression of the deficits:
 - (a) Temporal and spatial reorientation (use of external aid)
 - (b) Language: maintenance of the written and spoken language abilities (stimulation of verbal initiative during conversation on subjects of interest for the patients)
 - (c) Attention and concentration (attentive matrices)
 - (d) Praxis: work with paper and pencil (copying or painting pictures, manual activities with different materials) or more ecological ones (connecting the buttons, putting on the shoes, connecting the shoe-strings, putting on the coat, opening and closing pens, opening and using common objects etc).
 - (e) Visuo-perceptive deficits (exploration of paintings and of the environment)
- Maintenance of the AVQ (stimulation of the procedural memory in the activity of daily living)
- Maintenance of autobiographic memory
- Improving mood and well-being
 - (a) Games (cards, domino, bingo, goose game)
 - (b) Pleasant home activities (care of the grandson or of the garden)
- Emotional management of the patients (anxiety, depression, anger)
- Psychological support of caregivers (planned conversations at the beginning and end of treatment, conversations upon caregiver's request or to educate the caregivers to stimulate the patients at home).

The activities for these patients had been chosen to respect the following criteria:

- Asserting the dignity of the patients
- Not emphasizing the difficulties of the patients but supporting their residual abilities
- Preferring pleasant activities
- Respecting individual personality (taste, preferences)
- Supporting spontaneous participation
- Aiding the patient to establish social roles (inside the family or the entourage of friends, and inside the group of cognitive stimulation)
- Favoring self-esteem

The clinical sessions were structured in the following way: greetings of the therapist to welcome the patients and their relatives (the wife for a patient and the daughter for the other). The greetings were very affectionate: the aim was to let the patient and their families know themselves, and to favour the relationship between the therapist and the patient and between the therapist and the relatives. The objective was, also, a global care of the patients in order to create positive feelings and motivate the patient to come to the hospital for the session of cognitive rehabilitation spontaneously. After the first greetings the therapist moved with the patients to a wide, luminous receiving room in order to begin the work.

The patients sat down one beside the other and the therapist took a place near them and not in the classic position from behind a writing desk, in order not to break the relaxing and pleasant atmosphere that had been created. The patients in the first stages of the disease are often aware of their cognitive deficits, they feel themselves defident towards the other people and therefore are victims of anxiety and depression much more than the older ones. That's why we underline the importance of maintaining a good and positive mood as the base of the therapy.

After a short talk to find out how they felt that day and how the last week went on, the therapist began a first session of temporal and spatial reorientation taking advantage of personal calendars that the patients took home and were used to consult daily with their relatives. This aspect must be emphasised because it evidences how much is important for the patient to continue the cognitive stimulation at home in order to create that positive routine that contributes to maintaining and increasing residual cognitive and functional abilities.

During the session the therapist stimulated one specific cognitive function or purposed recreational occupations (see above).

After 45 minutes, the dismissal was similar to the beginning of the training session: the therapist returned with the patients to the relatives who were in the waiting room. The therapist, with the aid of the patients, reviewed with the caregiver the activities carried out during the session and then said good-bye to all, reminding them of the next meeting date which was also written by the patients on their personal agenda.

Apart from the general objectives already mentioned, the training had the specific aim to favor the acquaintance between the two families (the patients and their relatives go out together during the week end in order to spend a little time taking walks or drinking coffee and talking together) to give psychological and psychoeducational support to the caregiver and to the patients as they request.

Even if the Alzheimer disease showed a rapid course in these two patients it demonstrated positive results improving patients' mood and self-esteem and ameliorating the caregivers abilities to cope with the disease.

The experience surely has, also, shown that the small group (2 or 3 people) is a profitable formula for the treatment of middle-aged AD patients. Other experiences would be useful in order to improve the protocol of treatment for this type of patient but we are sure that it's important to take total care of the person concerning his/her cognitive, social, relational, psychological and emotional aspects.

REFERENCES

- Abrahams, JP; Wallach HF; Divens S. Behavioral improvement in long-term geriatric patients during an age-integrated psychosocial rehabilitation program. *J. Am. Geriatr. Soc.*, 1979, 27:218-221.
- Alexopoulos, GA; Abrams, RC; Young, RC; Shamoian, CA. Cornell scale for depression in dementia. *Biol. Psych.*, 1988, 23:271-284.
- Arkin, SM. Student-led exercise sessions yield significant fitness gains for Alzheimer's patients. *Am. J. Alzheimers Dis. Other Demen.*, 2003, May-Jun, 18(3), 159-70.

- Arkin, S. Language-Enriched Exercise Plus Socialization slows Cognitive Decline in Alzheimer's Disease. *Am. J. Alzheimers Dis. Other Demen.*, 2007, Feb/Mar, volume 22 Number., 1, 62-77.
- Babins, LH; Dillon, JP; Merovitz, S. The effects of Validation Therapy on disorientated elderly. *Activities, Adaption and Aging*, 1988, 12, 73-86.
- Baillon, S; Van Diepen, E; Prettyman, R; Redman, J; Rooke, N; Campell, RA. comparison of the effects of Snoezelen and reminiscence therapy on the agitated behaviour of patients with dementia. *Int. J. Geriatr. Psychiatry.*, 2004, Nov;19(11), 1047-52.
- Baines, S; Saxby, P; Ehlert, K. Reality orientation and reminiscence therapy: a controlled cross-over study of elderly confused people. *Br. J. Psychiatry.*, 1987, 151, 222-231.
- Baker, R; Bell, S; Thomas, P; Assey, J; Wareing, LA. A randomized controlled trial of the effects of multisensory stimulation for people with dementia. *British Journal of Clinical Psychology.*, 2001, 40, 81-96.
- Beck, AT; Ward, CH; Mendelson, M; Mock, JE; Erbaugh, JK. An inventory for measuring depression. *Arch. Gen. Psychiatry.*, 1961, 561-571.
- Bird, M; Alexopoulos, P; Adamowicz, J. Success and failure in five case studies: Use of cued recall to ameliorate behavior problems in senile dementia. *Int. J. Geriatr. Psychiatry.*, 1995, 10, 305-311.
- Bird, M; Kinsella, G. Long term cued recall of tasks in senile dementia. *Psychol. Aging.*, 1996, 11, 45-56.
- Bleathman, C; Morton, I. Validation therapy with the demented elderly. *J. Adv. Nurs.*, 1988, 13, 511-514.
- Brook, P; Degun, G; Mather, M. Reality Orientation, a therapy for psychogeriatric patients: a controlled study. *Brit. J. Psychiatry.*, 1975, 127, 42-45.
- Burgeois, MS; Burgio, LD; Schultz, R; Beach, S; Palmer, B. Modifying repetitive verbalization of community-dwelling patients with AD. *Gerontologist.*, 1997, 37, 30-39.
- Burnside, I; Haight, B. Reminiscence and life review: therapeutic interventions for older people., 1994, 19, 55-61.
- Camp, CJ; Foss, JW. Designing ecologically valid intervention for persons with dementia. In: Payne, DG; Conrad, FG. (eds): Intersection in basic and applied memory research. *New York: Springer.*, 1997, 311-315.
- Cipriani, G; Bianchetti, A; Trabucchi, M. Outcomes of a computer-based cognitive rehabilitation program on Alzheimer's disease patients compared with those on patients affected by mild cognitive impairment., 2006, Nov-Dec, 43(3):327-35.
- Chung, JC; Lai, CK; Chung, PM; French, HP. Snoezelen for dementia *Cochrane Database Syst. Rev.*, 2002, (4), CD003152.
- Clare, L; Wilson, BA; Breen, K; Hodges, JR. Errorless learning of face-name association in early Alzheimer's disease. *Neurocase.*, 1999, 5, 37-46.
- Clare, L; Wilson, BA; Carter, G; Breen, K; Gosses, A; Hodges, JR. Intervening with everyday memory problems in dementia of Alzheimer type: an errorless learning approach. *J. Clin. Exp. Neuropsychol.*, 2000, 22, 132-146.
- Clare, L; Wilson, BA; Carter, G; Roth, I; Hodges, JR. Relearning face-name associations in early Alzheimer's disease. *Neuropsychology.*, 2002, Oct, 16(4):538-47.
- Cummings, JL; Mega, M; Gray, K; Rosenberg-Thompson, S; Carusi, DA; Gornbein, J. The Neuropsychiatric Inventory: comprehensive assessment of psychopathology in dementia. *Neurology.*, 1994, 44, 2308-2314.

- De Vreese, LP; Neri, M. Ecological impact of combined cognitive training programs (CPT) and drug treatment (ChE-I) in Alzheimer's disease. *Int. Psychogeriatr.*, 1999 a, 11(suppl),S187.
- De Vreese, LP. Cognitive rehabilitation procedures in cognitively challenged elderly. Paper presented at the 3rd International Symposium on "Advances in geriatric psychiatry: instruments for diagnosis, prognosis and rehabilitation". Department of Psychiatry, *University of São Paulo, Brasil.*, 1999, b.
- Dooley, NR; Hinojosa, J. Improving quality of life for persons with Alzheimer's disease and their family caregivers: brief occupational therapy intervention. *Am. J. Occupational Therapy.*, 2004, 58, 561-569.
- Dunn, J; e Clare, L. Learning face-name association in early-stage dementia: Comparing the effects of errorless learning and effortful processing *Neuropsychol Rehabil.*, 2007, Jul 7, 1-20.
- Farina, E; Fioravanti, R; Chiavari, L; Imbornone, E; Pomati, S; Pinardi, G; Alberoni, M; Mariani, C. Functional Living Skills Assessment: A standardized instrument built to monitor activities of daily living in demented patients: preliminary data. *J. Neurol.*, 1999, 246, (suppl. 1), I/101.
- Farina, E; Fioravanti, R; Chiavari, L; Imbornone, E; Alberoni, M; Pomati, S; Pinardi, G; Pignatti, R; Mariani, C. Comparing two programs of cognitive training in Alzheimer's disease: a pilot study. *Acta Neurologica Scandinavica.*, 2002, 105(5), 365, 371.
- Farina, E; Mantovani, F; Fioravanti, R; Pignatti, R; Chiavari, L; Imbornone, E; Olivotto, F; Alberoni, M; Mariani, C; Nemni, R. Evaluating two group programmes of cognitive training in mild to moderate AD: is there any difference between a "global" stimulation and a "cognitive-specific" one? *Aging Ment Health.* March., 2006 a, 10(3), 1-8.
- Farina, E; Mantovani, F; Fioravanti, R; Rotella, G; Villanelli, F; Imbornone, E; Olivotto, F; Tincani, M; Alberoni, M; Petrone, E; Nemni, R; Postiglione, A. Efficacy of recreational and occupational activities associated to psychologic support in mild to moderate Alzheimer disease: a multicenter controlled study. *Alzheimer Dis. Assoc. Disord.* Oct-Dec., 2006 b, 20(4), 275-82
- Feil N. Il metodo Validation. Milano: Sperling and Kupfer, 1996.
- Feil, N. The validation breakthrough: simple techniques for communicating with people with "Alzheimer's-type dementia". Baltimore: *Health Promotion Press.*, 1993.
- Finnema, E; Dröes, RM; Ribbe, M; Van Tilburg, W. The effects of emotion-oriented approaches in the care for persons suffering from dementia: a review of the literature. *Int. J. Geriatr. Psychiatry.*, 2000, Feb, 15(2):141-61.
- Fitzsimmons, S. Dementia practice guidelines for recreation therapy. Alexandria, VA: *ATRA Publications*; 2003.
- Florenzano, F. *La Reality Orientation in Psicogeriatrica*. Roma: Primerano, 1988.
- Gerber, GJ; Prince, PN; Snider, HG; Atchinson, K; Dubois, L; Kilgour, JA. Group activity and cognitive improvement among patients with Alzheimer's disease. *Hosp. Community Psychiatry.*, 1991, 42, 843-845.
- Gitlin, LN; Corcoran, M; Winter, L; Boyce, A; Hauck, WW. A randomized, controlled trial of a home environmental intervention: effect on efficacy and upset in caregivers and on daily function of persons with dementia. *Gerontologist.*, 2001, 41(1), 4-14.

- Goldwasser, AN; Auerbach, SM; Harkins, SW. Cognitive, affective and behavioural effects of Reminiscence Group Therapy on Demented elderly. *Int. J. Aging Hum. Dev.*, 1987, 25, 209-222.
- Guralnik, JM; Branch, LG; Cummings, SR; Curb, JD. Physical performance measures in aging research. *J Gerontol.*, 1989, 44, 141-146.
- Haslam, C; Gilroy, D; Black, S; Beesley, T. "How successful is errorless learning in supporting memory for high and low-level knowledge in dementia?" *Neuropsych. Reha.*, 2006, 16(5), 505-536.
- Head, DM; Portnoy, S; Woods, RT. The impact of reminiscence groups in two different settings. *In. J. Geriatr. Psychiatry*, 1990, 5, 292-302.
- Holmes, C; Knights, A; Dean, C; Hodkinson, S; Hopkins, V. Keep music live: music and the alleviation of apathy in dementia subjects. *Int. Psychogeriatr.*, 2006, Dec;18(4), 623-30.
- Hope, KW. "The effects of multisensory environments on older people with dementia". *Journal of Psychiatric and Mental Health Nursing.*, 1998, 5, 377-385
- Irish, M; Cunningham, CJ; Walsh, JB; Coakley, D; Lawlor, BA; Robertson, IH; Coen, RF. Investigating the enhancing effect of music on autobiographical memory in mild Alzheimer's disease. *Dement Geriatr. Cogn. Disord.*, 2006, 22(1), 108-20.
- Ishizaki, J; Meguro, K; Ohe, K; Kimura, E; Tsuchiya, E; Ishii, H; Sekita, Y; Yamadori, A. Therapeutic psychosocial intervention for elderly subjects with very mild Alzheimer disease in a community: the tajiri project. *Alzheimer Dis. Assoc. Disord.*, 2002, Oct-Dec;16(4), 261-9.
- Janseen, JA; Giberson, DL. Remotivation therapy. *J. Gerontol. Nurs.*, 1988, 14, 31-34.
- Jette, AM; Branch, LG. Impairment and disability in the aged. *J. Chronic Dis.*, 1985, 38, 59-65.
- Jones, M. Gentle Care: *Changing the experience of Alzheimer's Disease in a positive way.* Moira Jones Resources, Barnaby BC, Canada, 1996.
- Karlsson, I; Brane, G; Melin, E; Nyth, AI; Rybo, E. Effects of environmental stimulation on biochemical and psychological variables in dementia. *Acta Psychiatr. Scand.*, 1988, 77, 207-213.
- Kixmiller, JS. Evaluation of Prospective Memory Training for Individuals with Mild Alzheimer's Disease *Brain and Cognition.*, 2002, Jul, 49 (2), 237-41.
- Kramer, AF; Erickson, KI. Capitalizing on cortical plasticity: influence of physical activity on cognition and brain function. *Trends Cogn. Sci.*, 2007, Aug, 11(8), 342-8.
- Koger, SM; Brotons, M. Music therapy for dementia symptoms (Cochrane Review). In: The Cochrane Library, Issue 4, 1999, Oxford: Update Software, 1999.
- Koh, K; Ray, R; Lee, J; Nair, A; Ho, T; Ang, P. Dementia in elderly patients: can the 3R mental stimulation programme improve mental status? *Age Ageing.*, 1994, 23, 195-199.
- Kongable, LG; Buckwalter, KC; Stolley, JM. The effects of pet therapy on the social behavior of institutionalized Alzheimer's clients. *Arch. Psychiatric. Nurs.*, 1989, 3, 191-198.
- Krebs-Roubicek, EM. Group therapy with demented elderly. *Prog. Clin. Biol. Res.*, 1989, 317, 1261-1272.
- Kuriansky, J; Gurland, B. The performance test of activities of daily living. *Int. J. Aging Hum. Dev.*, 1976, 7, 343-352.
- Lawton, MP; Brody, EM. Assessment for older people: self-maintaining and instrumental activities of daily living. *Gerontologist*, 1969, 9, 179-186.

- Levy, LL. Psychosocial intervention and dementia, Part 1: State of the art, future directions. *Occupational Therapy in Mental Health*, 1987, 7, 69-107.
- Long, AP. & Haig, L. "How do clients benefit from Snoezelen? An exploratory study". *British Journal of Occupational Therapy*, 1992, 55, 103-106.
- Lowenstein, DA; Amigo, E; Duara, R; Guterman, A; Hurwitz, D; Berkowitz, N; Wilkie, F; Weinberg, G; Black, B; Gittelman, B; Eisdorfer, C. A new Scale for the assessment of functional status in Alzheimer's Disease and Related Disorders. *J. Gerontol.*, 1989, 44, 114-121
- Mahurin, RK; De Bettignies, BH; Pirozzolo, FJ. Structured assessment of independent living skills: preliminary report of a performance measure of functional abilities in dementia. *J. Gerontol.*, 1991, 46:P-58-66.
- McKittrick, LA; Camp, CJ; Black, W. Prospective memory intervention in Alzheimer's disease. *J. Gerontology.*, 1992, 47, 337-343.
- Metitieri, T; Zanetti, O; Geroldi, C; Frisoni, GB; De Leo, D; Dello Buono, M; Bianchetti, A; Trabucchi, M. Reality orientation therapy to delay outcomes of progression in patients with dementia. A retrospective study. *Clin. Rehabil.*, 2001, Oct, 15(5), 471-8.
- Metzler-Baddeley, C. e Snowden, JS. "Brief Report: Errorless versus Errorful Learning as a Memory Rehabilitation approach in Alzheimer's Disease" *J. Clin. Exp. Neuropsychol.*, 2005, 27, 1070-79.
- Neal, M; Briggs, M. Validation therapy for dementia (Cochrane Review). In: The Cochrane Library, Issue 4, 1999. Oxford: *Update Software.*, 1999.
- Nobili, A; Riva, E; Tettamanti, M; Lucca, U; Liscio, M; Petrucci, B; Salvini Porro, G. The effect of a structured intervention on caregivers of patients with dementia and problem behaviors. A randomized controlled pilot study. *Alzheimer Dis. Assoc. Disord.*, 2004, 18, 75-82.
- Novak, M; Guest, C. (1980). Application of a multidimensional caregiver burden inventory. *Gerontologist*, 29, 798-780.
- Olazaràn, J; Muñiz, R; Reisberg, B; Peña-Casanova, J; del Ser, T; Cruz- Jentoft, AJ; Serrano, P; Navarro, E; Garcia, de la Rocha, ML; Frank, A; Galiano, M; Fernandez-Bullido, Y; Serra, JA; Gonzalez-Salvador, MT; Sevilla, C. "Benefits of cognitive-motor intervention in MCI and mild to moderate Alzheimer disease". *Neurology.*, 2004, Dec 28, 63(12), 2348-53
- Onder, G; Zanetti, O; Giacobini, E; Frisoni, GB; Bartorelli, L; Carbone, G; Lambertucci, P; Silveri, MC; Bernabei, R. Reality orientation therapy combined with cholinesterase inhibitors in Alzheimer's disease: randomised controlled trial. *Br. J. Psychiatry.*, 2005, Nov, 187, 450-5.
- Onor, ML; Trevisiol, M; Negro, C; Signorini, A; Saina, M; Aguglia, E. Impact of a multimodal rehabilitative intervention on demented patients and their caregivers. *Am. J. Alzheimers Dis. Other Demen.*, 2007, Aug-Sep, 22(4), 261-72.
- Orrell, M; Spector, A; Thorgrimsen, L; Woods, B. A pilot study examining the effectiveness of maintenance Cognitive Stimulation Therapy (MCST) for people with dementia. *Int. J. Geriatr. Psychiatry.*, 2005, May, 20(5), 446-51.
- Orten, JD; Allen, M; Cook, J. Reminiscence groups with confused nursing centre residents: An experimental study. *Soc. Work Health Care*, 1989, 14, 73-86.
- Parmalee, PA; Thuras, PD; Katz, IR; Lawton, MP. Validation of the Cumulative Illness Rating Scale in a geriatric residential population. *J Am Geriatr Soc*, 1995, 43:130-137)

- Pinkney, L. "A comparison of the Snoezelen environment and a music relaxation group on the mood and behaviour of patients with senile dementia". *British Journal of Occupational Therapy*, 1997, 60, 209-212.
- Reisberg, B; Ferris, SH; Franssen, E; Jenkins, EC; Wisniewski, KE. "Clinical features of a neuropathologically verified familial Alzheimer's cohort with onset in the fourth decade: comparison with senile onset Alzheimer's disease and etiopathogenic implications" Aging and Dementia Research Center, New York University Medical Center, New York 10016. *Prog. Clin. Biol. Res.*, 1989, 317, 43-54.
- Reisberg, B; Finkel, S; Overall, J; Schmidt-Gollas, N; Kanowski, S; Lehfeld, H; Hulla, F; Sclan, SG; Wilms, HU; Heininger, K; Hindmarch, I; Stemmler, M; Poon, L; Kluger, A; Cooler, C; Bergener, M; Hugonot-Diener, L; Robert, PH; Antipolis, S; Erzigkeit, H. The Alzheimer's disease activities of daily living international scale (ADL-IS). *Int. Psychogeriatr.*, 2001, Jun, 13(2), 163-81.
- Reisberg, B Diagnostic criteria in dementia: a comparison of current criteria, research challenges, and implications for DSM-V. *J. Geriatr. Psychiatry Neurol.*, 2006, Sep, 19(3), 137-46. Review.
- Reuben, DB; Siu, AL. An objective measure of physical function of elderly outpatients The Physical Performance Test. *J. Am. Geriatr. Soc.*, 1990, 38, 1105-1112.
- Reuben, DB; Siu, AL; Kimpau, S. The predictive validity of self-report and performance-based measures of function and health. *J. Gerontol.*, 1992, 47, M106-110.
- Robb, SS; Stegman, CE; Wolanin, MO. No research versus research with compromised results: a study of Validation Therapy. *Nurs. Res.*, 1986, 35, 113-118.
- Rolland, Y; Pillard, F; Klapouszczak, A; Reynish, E; Thomas, D; Andrieu, S; Rivière, D; Vellas, B. "Exercise program for nursing home residents with Alzheimer's disease: a 1-year randomized, controlled trial". *J. Am. Geriatr. Soc.*, 2007, Feb, 55(2), 158-65.
- Rovner, BW; Steel, CD; Shmueli, Y; Folstein, MF. A randomized trial of dementia care in nursing homes. *J. Am. Geriatr. Soc.*, 1996, 44, 7-13.
- Sherratt, K; Thornton, A; Hatton, C. Music interventions for people with dementia: a review of the literature. *Aging Ment. Health*, 2004, 8(1), 3-12.
- Sobel, BP. Bingo vs. physical intervention in stimulating short-term cognition in Alzheimer's disease patients. *Am. J. Alzheimers Dis. Other Demen.*, 2001, Mar-Apr, 16(2), 115-20.
- Spaull, D; Leach, C. Frampton, I. "An evaluation of the effects of sensory stimulation with people who have dementia". *Behavioural and Cognitive Psychotherapy*, 1998, 26, 77-86.
- Spector A; Orrell, M; Davies, S; Woods, B. Reality orientation for dementia (Cochrane Review). In: The Cochrane Library, Issue 4, 1999a. Oxford: Update Software, 1999.
- Spector, A; Orrell, M; Davies, S; Woods, RT. Reminiscence for dementia (Cochrane Review). In: The Cochrane Library, Issue 4, 1999b. Oxford: Update Software, 1999.
- Spector, A; Thorgrimsen, L; Woods, B; Royan, L; Davies, S; Butterworth, M; Orrell, M. Efficacy of an evidence-based cognitive stimulation therapy programme for people with dementia: randomised controlled trial. *Br. J. Psychiatry.*, 2003, Sep, 183, 248-54.
- Spector, A; Orrell, M; Davies, S; Woods, B. Reality orientation for dementia. Cochrane Database Syst Rev. 2000, (4), CD001119. Review. Update in: *Cochrane Database Syst Rev.*, 2000, (3), CD001119
- Svansdottir, HB; Snaedal, J. Music therapy in moderate and severe dementia of Alzheimer's type. A case control study *Int. Psychogeriatr.*, 2006, Dec;18(4), 613-21.

- Tarraga, L; Boada, M; Modinos, G; Espinosa, A; Diego, S; Morera, A; Guitart, M; Balcells, J; Lopez, OL; Becker, JT. A randomised pilot study to assess the efficacy of an interactive, multimedia tool of cognitive stimulation in Alzheimer's disease. *J. Neurol. Neurosurg. Psychiatry.*, 2006, Oct, 77(10):1116-21.
- Talassi, E; Guerreschi, M; Feriani, M; Fedi, V; Bianchetti, A; Trabucchi, M. Effectiveness of a cognitive rehabilitation program in mild dementia (MD) and mild cognitive impairment (MCI): a case control study. *Arch. Gerontol. Geriatr.* 2007, 44 Suppl 1:391-9.
- Taulbee, LR; Folsom, JC. Reality orientation for geriatric patients. *Hosp Commun Psychiatry* 1966, 17, 133-135.
- Teri, L; Gibbons, LE; McCurry, SM; Logsdon, RG; Buchner, DM; Barlow, WE; Kukull, WA; LaCroix, AZ; McCormick, W; Larson, EB. Exercise plus behavioral management in patients with Alzheimer Disease. *JAMA*, 2003, 290:2155-2022.
- Teri, L; Truax, P; Logsdon, R; Uamato, J; Zarit, S; Vitaliano, PP. Assesment of behavioral problems in dementia: the Revised Memory and Behavior Problem Checklist. *Psychol. Aging*, 1992, 7, 627-631.
- Teri, L. Behavioral treatment of depression in patients with dementia. *Alzheimer Dis. Assoc. Disord.*, 1994, 8(suppl. 3):66-74.
- Toseland, RW; Diehl, M; Freeman, K; et al. The Impact of Validation Group Therapy on Nursing Home Residents with Dementia. *J. Appl. Gerontol.*, 1997, 16, 31-50.
- Van de Winckel, A; Feys, H; De Weerd, W; Dom, R. Cognitive and behavioural effects of music-based exercises in patients with dementia. *Clin. Rehabil.* 2004 May, 18(3), 253-60
- Van der Linden, M; Juillerat, AC. Prise en charge des déficits cognitifs chez les patients atteints de maladie d'Alzheimer. *Rev. Neurol.*, 1998, 154, 137-143.
- Verkaik, R; van Weert, JC; Francke, AL. "The effects of psychosocial methods on depressed, aggressive and apathetic behaviors of people with dementia: a systematic review". *Int. J. Geriatr. Psychiatry.*, 2005 Apr, 20(4), 301-14. Review.
- Vink, AC; Birks, JS; Bruinsma, MS; Scholten, RJ. Music therapy for people with dementia. *Cochrane Database Syst. Rev.*, 2004, (3), CD003477.
- Vitali, S. La metodologia Gentle Care – Gentle Care model. *G Gerontol*, 2004, 52, 412-417.
- Williams ME Identifying the older person likely to require long-term care services. *J. Am. Geriatr. Soc.*, 1987, 35, 761-766.
- Williams, CL; Tappen, RM. "Effect of exercise on mood in nursing home residents with Alzheimer's disease". *Am. J. Alzheimers Dis. Other Dement.* 2007 Oct-Nov, 22(5), 389-97
- Wilson, B; Cockburn, J; Baddeley, A. *Test di memoria comportamentale Rivermead*. Organizzazioni Speciali, Firenze, 1990.
- Wilson, BA; Evans, JJ. Error-free learning in rehabilitation of people with memory impairment. *J. Head Trauma Rehab.*, 1996, 11, 54-64.
- Yesavage, JA; Brink, TL; Rose, TL; et al. Development and validation of a geriatric depression screening scale: a preliminary report. *J. Psychiatric Res.*, 1982-83, 17, 37-49.
- Zanetti, O; Binetti, G; Magni, E; Rozzini, L; Bianchetti, A; Trabucchi, M. Procedural memory stimulation in Alzheimer's disease: impact of a training programme. *Acta Neuro. Scand.*, 1997a, 95, 152-157.
- Zanetti, O; Zanieri, G; De Vreese, LP; Frisoni, G; Binetti, G; Trabucchi, M. Utilizing an electronic memory aid with Alzheimer's disease patients. *A study of feasibility*. Paper presented at the 6th International Stockholm/Springfield Symposium on advances in Alzheimer Therapy, Stockholm, Sweden, 2000.

Zanetti, O; Zanieri, G; Di Giovanni, G; et al. Effectiveness of procedural memory stimulation in mild Alzheimer's disease: a controlled study. *Neuropsychol. Rehabil.*, 2001, 11, 263-272.

Chapter 9

THE COGNITIVE EFFECTS OF ANXIETY ON SEXUAL AROUSAL

Philippe Kempeneers^{1,2}, Romain Pallincourt² and Sylvie Blairy³

¹University of Liege, Unit of Clinical Psychology, Belgium

²Alexians' Psychiatric Hospital, Henri-Chapelle, Belgium

³University of Liege, Unit of Cognitive-Behavioural Clinical Psychology, Belgium

ABSTRACT

Anxiety and sexual arousal have often been considered as incompatible. Since the end of the 20th Century, however, researches have impaired theories centred on the inhibitory effect of the stress and on peripheral explanations; they rather focus attention on the complexity of the relations between the two states and on cognitive mechanisms.

Now sexual arousal tends to be regarded as a complex response that requires the convergent interpretation of internal and external stimuli. Anxiety may have different effects on this process, sometimes neutral, sometimes facilitating and sometimes inhibitory.

On the one hand, anxiety can trigger a vegetative emotional reaction that may be associated to a concomitant erotic stimulation. Thus, anxiety facilitates the sexual response: this can be called a *priming effect*. This effect is regularly observed in labs, mainly among women. It likely also works in certain compulsive sexual behaviours or, more commonly, in those numerous persons that report being sexually aroused when stressed.

On the other hand, anxiety can cause a massive irruption of non erotic cues in working memory. Therefore, cognitive function available for treating erotic stimuli is diminished and sexual response is impaired. This is an effect of *cognitive interference*. A trait called *erotophobia* could be regarded as a vulnerability factor to cognitive interference. Erotophobic subjects are characterized by a trend to focus upon danger-related information when they are in a sexual situation and by a higher risk of sexual dysfunction.

Anxiety is a recognised etiological factor in the domain of sexual dysfunctions. Previous researches have reported reduced sexual responses in individual suffering from anxiety

(Bodinger et al., 2002; Leiblum et al., 2007; Meana & Nunnick, 2006; Purdon & Holdaway, 2006; Rellini, 2008.) Whether this is caused by concerns regarding self-image, one's physical appearance, one's performance as a lover or the fear of getting pregnant, or fears of being abandoned or worries relating to everyday difficulties, or whether it is the result of a social phobia, a panic disorder or a history of sexual abuse, all the observations converge towards one point: anxiety and sexual stimulation are not a good match.

Among clinicians, it was widely believed, for a long time, that anxiety was an antagonistic state of sexual responses. Many authors have theorised on this issue. The most well known, Masters and Johnson (1970) described the now famous performance anxiety mechanism: worried about their sexual performance, dysfunctional patients cannot indulge in pleasure; they behave like a worried spectator, concerned about their own performance, thus managing to inhibit the sexual responses for which they are hoping and praying. This form of vicious circle was presented as the primary cause of chronic sexual dysfunction. In 1974, Kaplan pointed out that other causal factors were sometimes added to the anxiety of performance, which were more deeply rooted in the history of the subject but also related to anxiety: the fear of intimacy, for instance, the feeling of guilt associated with sexuality or the fear of being abandoned. The fact is that up until quite recently, clinicians tended to represent anxiety and sexual arousal as irreconcilable states. They were more or less explicitly inspired by the works of Wolpe (1958) on reciprocal inhibition. The principle of reciprocal inhibition postulated an incompatibility between certain neurovegetative states. Specifically, anxiety, a state where the activity of the sympathetic system predominates, was considered to be incompatible with sexual arousal, whose initiation requires parasympathetic activity. According to Wolpe (1958), anxiety and arousal states are mutually exclusive. Wolpe's theory attributes the inhibitory effect of one state upon the other to a direct physiological causality effect.

In the beginning, the theory of reciprocal inhibition was very appealing to clinicians sensitive to the almost constant presence of elements of anxiety implicit in functional problems. However, beyond the field of sexual dysfunctions, various elements caused doubt regarding such a simple and direct inhibitory relationship. First, several anecdotes evoked the possibility of sexual arousal stimulated by stress. For examples, stories of lovers who were stimulated by the fear of being caught in the act, stories of couples where sexual relations following a "good old" argument were all the more intense, or stories of rape carried out in the heat of anger. Clinical observations then became systematic. Since the work of Marshall, Laws & Barbaree (1990), we now know that certain types of criminal sexual behaviour are stimulated by stress or are the result of humiliation. It is also the case for certain cases of paraphilia and for compulsive sexual behaviour where stress is often a trigger (Bancroft & Vukadinovic, 2004; Kafka, 2007). Moreover, surveys carried out among the general population also showed that anxiety and arousal can sometimes go hand in hand. For instance, the survey published in 2003 by the Bancroft team showed that 28.3 % of the interviewed men have reported that anxiety put a strain on their sexual interests, while 20.6 % considered it to be stimulating. Twenty percent is fairly significant. It is highly unlikely that we are only dealing with marginal cases of compulsive or deviant sexuality. The survey by Lykins, Janssen and Graham carried out in 2006 on female students also showed similar results. In this survey, 10 % of the students reported to be sexually stimulated by anxiety. Clearly, anxiety is not only an antagonist of sexual functioning; it can also, and quite often, be an agonist. This rapidly led to the belief that anxiety-arousal relations were probably more

complex than the reciprocal inhibition theory suggested. During the last two decades, we have gone from a theory centred on inhibition and the peripheral physiological mechanisms to a theory insisting more on the complexity of the relations between the two states and on the cognitive explicators.

THE CONTRIBUTION OF PLETHYSMOGRAPHY

As mentioned above, the observations made outside the field of sexual dysfunctions have cast doubt on the theory of reciprocal inhibition. Consequently, numerous studies have investigated the understanding of anxiety-arousal relations. In this context, the plethysmographic techniques were often employed. Plethysmography allows sexual arousal to be assessed in a subject by providing a direct description of the person's state. The level of arousal is inferred from genital vasocongestion. In men, a sensor ring is fitted around the penis; it is sensitive to variations in pressure, thus allowing the tumescence of the organ to be measured. This is what is known as *penile plethysmography*. In women, a vaginal probe sensitive to colour variations in the wall of the vagina allows the extent of the blood flow in this area to be determined. This is *vaginal photoplethysmography*. The measurements generally take place when the subject is exposed to erotic stimuli, either audio (recorded material) or video (explicit films).

Initial Experiments

The first experimental arguments against the theory of reciprocal inhibition were put forward by Hoon, Wincze and Hoon in 1977 on female subjects, and by Wolchik et al. in 1980 on male subjects. They were reproduced in 1990 by Palace and Gorzalka on a sample of women. In these experiments, before viewing erotic images, half the subjects were exposed to an emotional film that induces anxiety (accident scenes), and the other half of subjects were exposed to an emotionally neutral film (the control condition.) The participants' sexual arousal was measured. The result showed that sexual arousal among participants firstly exposed to anxiogenic stimulus was not inhibited compared to participants firstly exposed to a neutral film. On the contrary, in the studies by Hoon et al. and Palace and Gorzalka, the initial exposure to an anxiogenic stimulus even seemed to facilitate arousal. Such results did not support the idea of an incompatibility between anxiety and arousal states. The observed priming effect of the one on the other observed in women even tended to support the opposite theory of psychophysiological processes common to both states.

Sympathetic Activity

Sympathetic activity was considered by Wolpe as the physiological foundation of the anxious inhibition of sexual reactivity. The experiments of Hoon et al. and Wolchik et al. did not completely invalidate this mode of action. Indeed, it was possible that the so-called anxiogenic stimuli did not provoke a sufficiently intense sympathetic reaction to exercise an

inhibitory effect on arousal. However, Lange et al. (1981) and Meston and Heiman (1998) had directly stimulated the sympathetic system using chemicals. Lange and his team injected male subjects with effective doses of epinephrine, a sympathicomimetic substance, just before being exposed to erotic films. They compared their sexual arousal with subjects receiving an injection of a placebo. No difference emerged. Their results were in line with the results of Wolchik's previous studies (1980). Meston and Heiman (1998), administered ephedrine, another sympathicomimetic substance to female subjects and reported a slight increase of arousal compared to the placebo group. Here, the results were the same as those of the initial experiment by Hoon et al. (1977). Similar results were also obtained by Meston and Gorzalka (1995, 1996) where the sympathetic activity of female subjects was induced through physical exercise. In conclusion, it appears that anxiety and the accompanying sympathetic activity are perfectly reconcilable with sexual arousal; they may even slightly encourage it: this is far from the principle of reciprocal inhibition.

Experimental Reproduction of Performance Anxiety

Wolpe's theory is clearly not the most pertinent theory to explain the links between anxiety and arousal. However, anxiety is definitely almost a constant in clinical dysfunctional tables. Therefore, it is possible that sexual anxiety has particularities that distinguish it from other negative emotions. The inhibition of arousal could be the result of perceptual and cognitive components specific to performance anxiety. Masters and Johnson, who considered performance anxiety to be the main factor responsible for arousal problems, insisted on the specific attitude caused by this type of fear: the patients became *spectators* of their own performance rather than the *actors*. Isn't it this particular mental state that characterises sexual anxiety and renders it incompatible with sexual arousal?

In order to test this hypothesis of a specificity of performance anxiety, Barlow, Sakheim and Beck attempted to reproduce the appearance conditions in an experiment in 1983. They measured arousal in male subjects who were given erotic films to watch after they had been threatened with electric shocks if their erectile performance did not reach an acceptable level. Arousal in these subjects, who were supposedly made anxious regarding their sexual performance, was compared to the arousal of subjects, on the one hand, who were also threatened with shocks but not in relation to their erectile performance, and, on the other hand, to subjects who had not been threatened. The purpose of the study was to compare the respective impact of performance anxiety (first condition), anxiety not linked to performance (second condition) and the absence of anxiety (third condition). The results were completely opposite to what the clinical considerations of Masters and Johnson predicted. Not only was sexual arousal greater in the threatened subjects compared with those who had not been threatened but, what's more, sexual arousal in the subjects threatened in relation to their erectile performance was even greater than in the subjects who were threatened, though not in relation to their sexual responses.

In 1990, Hale and Strassberg operationalized performance anxiety in a slightly different way. Male subjects were exposed to erotic stimuli. The sexual anxiety was provoked by somewhat hurtful intervention of an experimenter after an initial phase of plethysmographic measurements: when the experimenter examined the first set of results, he pretended to be disappointed that the level of erection achieved was lower than normal. The experiment then

continued and the arousal obtained during the second phase of the experiment by the supposedly disconcerted subjects with respect to their sexual performance, was compared with the control subjects; on the one hand, the subjects who were made anxious without any link to erectile performance (threat of electric shocks independent of the levels of erection) and, on the other hand, subjects who were not made anxious. Contrary to Barlow et al., (1983) Hale and Strassberg (1990) observed an inhibiting effect on sexual arousal caused by stress. However, the mode of anxiety induction had no specific effect: the subjects who were made anxious in relation to their erectile performance or in relation to the possibility of an electric shock showed equivalent levels of arousal, in both cases lower than the control subjects who suffered no pressure or threats.

In 1997, Elliot and O'Donohue carried out a similar experiment with women. Performance anxiety was induced by making the subjects believe that the experimental session would be filmed on video. Research assistants would watch the recordings later and assess the subjects according to levels of "attraction", "personality" and "body language". This procedure did not provoke any significant reduction in sexual arousal: it remained equivalent to that of the control subjects.

In conclusion, the results from these three experiments do not support the hypothesis of a particularity of performance anxiety that endows it with an actual inhibitory effect on sexual arousal.

The Exception of Dysfunctional Subjects

In experimental conditions, anxiety does not appear as a typically inhibitor variable of sexual responses. Further, the links to performance changes nothing. In most plethysmographic studies, it has no impact on arousal, in fact, if anything, it encourages it (Barlow, Sakheim & Beck, 1983; Elliot & O'Donohue, 1997; Hoon, Wincze & Hoon, 1977; Lange et al., 1981; Meston & Gorzalka, 1996; Meston & Heiman, 1998; Palace & Gorzalka, 1990; Wolchik et al., 1980). It is only in Hale and Strassberg's study (1990) that it seemed to act against arousal. However, clinicians tended massively to consider anxiety as one of the major causes of sexual dysfunction. Were clinical intuitions really so wrong? Or maybe the inhibitory effect of anxiety is due to particularities present in clinical subjects and not in experimental subjects?

The results from an experiment conducted in 1987 by Beck, Barlow, Sakheim and Abrahamson on clinical subjects support this hypothesis. The authors have employed the paradigm of the threat of shocks used by Barlow et al. in 1983. They compared plethysmographic measurements taken on men with non-organic erectile problems with those from men with no history in erectile dysfunction. Like Barlow et al. in 1983, they noticed that anxiety induced by the threat of shocks in non-clinical subjects had no effect at all or even slightly facilitated arousal; however, in dysfunctional subjects, it clearly had an inhibitory effect.

The results from Palace and Gorzalka (1990, *op. cit.*) and Meston and Gorzalka (1996, *op. cit.*) also support the theory of a different response to anxiety in dysfunctional subjects. The priming effect of anxiety on arousal observed in non-clinical female subjects was not observed as clearly in women suffering from a functional orgasm disorder.

Overall, these results corroborate the clinical point of view of anxiety being responsible for sexual dysfunctions: anxiety can well and truly have an antagonistic effect on sexual responses; only, the anxiety-arousal relationship is not as simple and linear as initially suggested. To be specific, the inhibitory effect of anxiety probably requires the intervention of a third-party mechanism. If this mechanism is absent, as would be the case in most non-clinical subjects in the plethysmographic experiments, then anxiety has no impact on arousal, or even potentialises it, and if it is present, which would be the case in dysfunctional patients, then anxiety inhibits arousal. This raises the following question: what is the third-party mechanism without which anxiety does not inhibit anything?

Cognitive Interference

Several studies converge towards designating *distraction* as an agent that is directly responsible for the inhibition of sexual responses.

In 1976, Geer and Fuhr had shown that arousal in male subjects exposed to erotic recordings diminished when they were subjected to distracting auditory stimuli at the same time. In 1979, an experiment by Farkas, Sine and Evans led to the same observation. In 1985, Adams, Haynes and Brayer showed that the same was true in female subjects.

Based on a literature review carried out by Barlow's team between 1985 and 1994, Sbrocco and Barlow (1996) concluded that distraction brought non-clinical subjects down to the same level of sexual arousal as clinical subjects affected by anxiety, the idea being that the latter were already distracted by their anxious preoccupations alone. All in all, what distinguishes functional and dysfunctional subjects for Sbrocco and Barlow, is neither the presence of anxiety nor its intensity, or even the fact that it is related to performance – this seems commonly experienced by non-clinical subjects without this disrupting their sexual responses – but the fact that it has this particular power in dysfunctional subjects to divert their attention towards non-erotic considerations (e.g. a negative self-image, their partner's disappointment). The cause of sexual dysfunctions is now conceived in terms of cognitive interference. From this point of view, anxiety indirectly explains functional problems: it encourages interference, i.e. it diverts the attention from erotic stimuli to non-erotic stimuli, but it is neither a sufficient nor necessary condition to inhibit arousal. It is insufficient because anxiety cannot interfere with the attention dedicated to the erotic situation; in this case, it has no effect, and it is not necessary because stimuli and thoughts other than anxiogenic can also create an interference, mobilising attention to the detriment of the erotic situation.

The inhibitory role of cognitive interference was again confirmed by Elliot and O'Donohue (1997, op. cit.). As mentioned above, the anxiety induced in this study on female subjects had no influence on their arousal. However, the experiment also had a second aim which was to assess the effect of distracting stimuli. While viewing erotic recordings, some subjects had to listen to sentences and repeat them according to more or less simple or complex instructions. Here, the effect was clearly significant: the inhibition of arousal was directly proportional to the level of distraction.

Contrary to distraction, anxiety has therefore no specific inhibitory effect. When anxious subjects have a reduced level of arousal, anxiety has obviously provoked the diversion of their attention from the erotic situation. This cognitive way of thinking also provides elements

that explain the atypical results of Hale and Strassberg's study (1990, op. cit.), one of few to have found that anxiety induced through experimental manipulation gave rise to a reduction in sexual responses (see above). When questioned about the thoughts they had during the experiment, the stressed subjects' answers were quite distinct from those of the control subjects owing to the higher number of non-erotic preoccupations that had attracted their attention (i.e. "Why didn't I get an erection?", "Will the electric shock hurt me?")

Finally, in 2001, Koukounas and McCabe observed that sexual arousal in male subjects exposed to erotic films strongly correlated with the impression they said they had of their attention being fully absorbed by the film.

Finally, these studies have led to a better understanding of the nature of the anxious inhibition of sexual responses. We now think that cognitive interference is the true *modus operandi*

TOWARDS A COGNITIVE THEORY OF THE AROUSAL-ANXIETY RELATIONSHIP

It is now clear that anxiety can have various influences on arousal: it can have an inhibitory effect, via the *interference effect*, or play the role of facilitator, known here as the *priming effect*. Besides the studies that relate directly to sexual arousal, an additional series of work and concepts have enabled us to specify the possible nature of cognitive mechanisms involved in priming and interference effects. A cognitive theory of the arousal-anxiety relationship has begun to take shape.

The Priming Effect

Plethysmographic studies have not merely shown that, in the absence of the interference vector, anxiety and arousal remain perfectly compatible, they have also shown that the first could even have an agonistic effect on the second. The increase in sexual reactivity observed in subjects exposed to experimental conditions (Barlow et al., 1983; Hoon et al., 1977; Meston & Gorzalka, 1995, 1996; Meston & Heiman, 1998; Palace & Gorzalka, 1990) effectively provides objective support for the feeling reported by numerous people that stress in fact favours arousal. All that remains is to explain this effect. Various models elaborated in the domain of the psychology of emotion help to elucidate the issue.

It is now established that the production of emotions is a process comprised of several stages (Damasio, 2003; LeDoux, 1996). Firstly, a rapid and mostly unconscious analysis of the trigger situation is made. The operation mainly takes place in the amygdale; this is at the origin of a somewhat undifferentiated primary physiological reaction, essentially comprised of vagal modifications. Secondly, cortical connections come into play and determine a secondary processing of the stimuli during which the emotion is adjusted, specified and led to consciousness. At this stage, the information from the environment (signs of danger for instance, or indications of a pleasant event) will direct the interpretation of the experience, giving it a particular affective character (sometimes worrying, sometimes exciting). At the same time, the information concerning the internal state (primary vagal modifications)

confirms the emotional nature of the situation: "I can feel that it is affecting me". Thus, through an interactive process, the particular physiological and subjective characteristics of the emotion are revealed. The same is probably true for sexual arousal: internal feelings and the erotic stimuli mutually guide each other to create a specifically erotic emotion.

In numerous situations of everyday life, we can observe a coupling mechanism between the characteristics of the trigger stimulus and the primary physiological reaction. External and internal stimuli in some way mutually confirm each other, leading to the emotional experience. During this process, biases can however occur: the coupling normally expected between the primary physiological reaction and the characteristics of the trigger situation can indeed be altered by the intrusion of information that is foreign to the initial conditions. Thus, unexpected emotions are produced. Two experiments illustrate this bias in the sexual domain; their results showed that the sexual emotion can be caused by elements that are completely foreign to erotic stimuli. As such, they give us an idea of the mechanisms that probably contribute to the element that prime arousal through anxiety.

1. Valins (1972) reports having exposed male subjects to erotic slides. During this time, a device measured their heart rate and they were made to listen to the sound of their own heartbeat. At least that is what they thought because, in reality, the heartbeats they heard were manipulated by an experimenter who made the rhythm vary at random, increasing it when certain images were shown and reducing it for others. When they were asked to point out the photos they liked the most, the subjects showed a tendency to select those that were associated with a pseudo-modification of their heartbeat.
2. In an experiment conducted in 1974 by Dutton & Aron, male subjects had to cross a footbridge that overlooked a canyon. Straight after this stressful ordeal, an interview took place with a female researcher. During the interview, the researcher asked the subjects to make up a story based on the drawing of a woman, then, when they had to leave, she gave them her card. Compared with subjects who had the same interview with the same researcher, though without having had to cross the harrowing footbridge beforehand, a significantly higher number of the stressed subjects made up stories with a sexual content and contacted the researcher afterwards in the hope of seeing her again.

These two experiments showed that the sexual emotion may be encouraged by the perception of a physiological activation whose origin is absolutely not erotic. Produced through arbitrary manipulation by Valins or through a sensation of fear by Dutton and Aron, the perceived physiological activation is coupled with a sexual stimulus that is foreign to its cause but concomitant in such a way that the emotion develops or reinforces itself in a sexual direction. This mechanism probably also plays a role in the priming elements revealed by the plethysmographic studies: the physiological activation induced by stress is attributed to an erotic source, with the result of encouraging the emotion and sexual responses.

Sexual arousal is an experience that results from the converging interpretation, in an erotic sense, of a series of signals from both the internal and external environment. To be exact, it should be noted that the genital vasocongestion reaction does not signal the end of the arousal process. It is merely a stage in a process that is only finally expressed with the subjective sensation of arousal. The reader will undoubtedly have noticed that, without it

being their exclusive privilege, the priming effect seems to be more widespread among women. At the same time, the genital reaction measured by plethysmography in women is not necessarily accompanied by a conscious impression of arousal. In men, on the other hand, there are quite good correlations between plethysmographic measurements and subjective feeling of arousal. This inter-gender difference can undoubtedly be explained through the more external location of the male genital organs: this anatomical data means that in comparison to women, men have a greater number of perceptive retroactive channels; the physiological signs of their arousal are more accessible via the visual channel and tactile sensations, which all allow a closer adjustment of genital and subjective responses. Probably as a result of this, genital vasocongestion in women appears to be a less specific response of arousal, less differentiated or less accomplished than it is in men (Chivers, 2005). Regardless of gender difference, the relative imbalance between the genital response and the subjective feeling bears witness to the sequential nature of the sexual arousal process. From the primary physiological response to the subjective experience, arousal is an experience that occurs progressively, during cognitive processes of increasing complexity and through certain hazards such as possible attribution biases.

The Effect of Interference

Anxiogenic stimuli are not always interpreted in a pro-erotic sense. The priming effect of arousal through anxiety is not an absolute. It clearly is not the case in numerous individuals suffering from a functional arousal or orgasm disorder. For these people, sexual inhibition based on anxiety remains a tiresome reality. However, the explanation of the phenomenon no longer refers to an improbable physiological incompatibility of the two states but rather cognitive interference.

In individuals suffering from sexual dysfunction, the anxiety that occurs in a sexual situation seems to act as a source of distraction; it triggers an intense cognitive activity, focused on danger, which interferes with the processing of erotic stimuli. Typical sexual anxious preoccupations – “Is it going to work?”, “What does my partner think of me?” – or even everyday concerns, sometimes have this ability to overwhelmingly monopolise the subject’s attention, to the point where the remaining resources are insufficient to ensure the normal execution of a sexual response. Therefore, it is not stress in itself that is the efficient inhibitory factor but the degree of distraction that it causes in certain people.

Erotophobia and Emotional Stroop

Not everyone is as vulnerable to the effects of anxious interference. People who risk suffering from sexual dysfunction seem to have a particular profile that Byrne and Schutle (1990), and later Sbrocco and Barlow (1996), qualified as *erotophobia*. Erotophobia consists of a tendency to associate sexuality with ideas of danger. There is a cognitive and emotional structure similar to the one that can be found in numerous anxiety disorders, though in this case, the object is sexuality. Therefore, it is a *phobia* linked to sexuality.

It has now been demonstrated that, in anxious individuals, the cognitive processing of a stimulus in relation to their emotional difficulties is far more costly in terms of attention than

the processing of the same stimulus in a person who is not anxious. This phenomenon was objectivised using a variant of the Stroop test called *emotional Stroop*. Through the Stroop test, it is possible to measure the interference of one cognitive activity over another. In its classic form, the test consists of presenting the subject with a series of written words using different coloured ink; the person is instructed to name the colours of the inks used and not to read the words. The examiner takes note of how quickly the instruction is obeyed to name the colours, knowing that this speed depends on the ease with which the subject manages to inhibit the execution of an interfering activity, i.e. an automatic tendency to read the words presented. The effect of interference of reading over naming the colours is measured here in time units: the greater it is, the more time will be required to execute the instruction. Reading has become automatic in almost every literate person who is exposed to written words, and it is this automatic behaviour which, in the Stroop test, creates an activity that is capable of interfering with another, less banal activity, such as naming font colours. As regards the emotional Stroop, it introduces an additional variable, the affective connotation of the words given to read. This Stroop variant shows that the effect of interference also depends on the emotion – anxiety in particular – caused by the stimulus. For instance, in anxious people suffering from social phobias, that is who are anxious in social relations, concerned about rejection, they need more time to name the colour of ink that is used to write a critical word such as “humiliation”, than to name the colour of an affectively neutral word such as “geology”. However, this difference in reaction time is not found in people who do not suffer from a social phobia (Mattia, Heimberg & Hope, 1993). In the same way, there are longer reaction times in people with arachnophobia, with words such as “spider” or “web” (Lavy, Van den Hout & Arntz, 1993); or with words such as “suffocate” in people who suffer from panic disorder (McNally, Riemann & Kim, 1990); with words relating to a trauma experienced by the subject (e.g. “rape”, “Vietnam”) in the case of post-traumatic stress disorders (Kapsi, McNally & Amir, 1995; McNally, English & Lipke, 1993); and with words such as “accident” in people suffering from generalised anxiety (Martin, Horder & Jones, 1992). In anxious people, the reaction times are systematically longer for words that evoke their specific anxious concerns. The effect of interference due to the emotional load of the stimulus leads us to believe that in people who are sensitive to it, some specific themes provoke an automatic cognitive activity centred on the notion of danger. Absorbing a significant amount of the subject’s mental resources, this activity hinders the achievement of another task.

To our knowledge, erotophobic subjects have never been assessed using emotional Stroop-type tests, which would target words that evoke sexual situations. However, it would not seem to be excessively rash to suppose that the same would be true for these people as for other anxious subjects. Therefore, Kempeneers and Barbier (2008) suggest considering erotophobia as a factor of cognitive interference. In a sexual situation, erotophobic subjects would tend to develop a cognitive activity focused on the notion of danger. Encroaching upon the resources allocated to the processing of the situation’s erotic components, this activity would lead to an increased risk of sexual dysfunction in these subjects.

The Working Memory

The inhibitive power of distraction leads us to consider that these people are endowed with a limited ability to process information. Above a certain quantitative threshold, the

cognitive resources required to process a second supposedly distracting stimulus (i.e. non erotic) must be taken from those allocated to the processing of a primary stimulus (i.e. erotic). The concept of *working memory* seems to be adapted to the description of the process. According to Eysenck (1991) and Peretti & Ferreri (2004), in people suffering from chronic anxiety who are confronted with sensitive themes, it is as though the working memory is saturated by information relating to the management of a source of danger, to the point where the execution of other tasks is altered. The working memory is a concept that was proposed and developed by Baddeley (Baddeley, 1992; Baddeley & Hitch, 1974). On a schematic level, it can be compared with the random access memory of a computer. It is the functional entity that allows you to momentarily keep in mind elements of information that are useful to accomplish a task. These elements are taken from the external environment on the one hand – an erotic stimulus for instance – and from the internal environment on the other hand – memories of similar experiences, schemas of actions learnt, moral values evoked by the situation, etc. Contrary to other forms of memory allocated to storing information in the long term, the working memory functions in a transitory way. The information only spontaneously remains for a few seconds. This goes hand in hand with its limited availability: the mass influx of new information tends to suppress those relating to the tasks in hand. In the terms of this model, anxiety provokes a saturation of the working memory in erotophobic subjects to the detriment of the resources essential to the execution of sexual responses. Elements of information relating to the management of danger come to the fore and compete with the erotic information.

The Attentional Benefit of Anxiety

The work of Mandler (1984) on the attentional effects of emotions is also of interest. According to Mandler, stress always has the effect of increasing vigilance. This explains why anxiety can sometimes facilitate the execution of certain tasks. In 1908, Yerkes & Dodson had pinned down the non-linear character of the relationship between stress and the level of performance to tasks requiring attentional functions: stress was sometimes detrimental to performance, and sometimes it improved it. It seemed to the authors that the optimal level of performance resulted from moderate stress rather than the absence of stress, and that a level of stress that was too high tended to exert a detrimental effect on performance. In reality, Mandler specified in 1984 that the intensity of the emotion is probably not the decisive variable concerning the evolution of the performance; instead, it is the element on which the increased attention provoked by the stress is focused. If it is focused on the elements relating to the task in hand, it logically produces an increase in the level of performance. If, on the contrary, it is focused on elements that are external to the accomplishment of the task, then the subject is distracted and his/her performance is poorer. It is easy to transpose Mandler's model to the area of sexual performance. When anxiety suddenly appears in a sexual situation, there are two possible scenarios:

1. The majority of the subject's attention may be drawn to elements of danger that are foreign to the erotic task in hand. His/her working memory is saturated with information of a non-erotic nature resulting in a reduction in sexual performance.

This is a case of the interference effect which can be found in stressed erotophobic subjects in a sexual situation.

2. In the absence of such a mechanism that shifts the cognitive resources, attention is maintained on the information of an erotic nature. This information thus benefits from a positive attentional balance that can result in an improvement in sexual performance. Under these conditions, a priming effect is obtained. This tendency would be more likely to occur in non-erotophobic subjects.

It should be noted that the model elaborated based on the work of Mandler is situated at the opposite end of the scale to Wolpe's. While the latter considered anxiety and arousal to be natural antagonists, the former tends to consider them as naturally agonistic.

CONCLUSION

While anxiety can inhibit sexual responses, plethysmographic studies have shown that this is not always the case. According to the circumstances, anxiety sometimes hinders arousal and sometimes facilitates it. The anxiety-arousal relationship turns out to be more complex than Wolpe (1958), Masters & Johnson (1970) and Kaplan (1974) originally imagined; they considered these states as incompatible.

Finally, the decisive factor of sexual inhibition would appear to be cognitive interference, distraction. It is only when anxiety causes a distraction from erotic stimuli that it may be considered responsible for sexual inhibition. This is not the case for everybody; some people are more prone than others and this tendency seems to be a characteristic of people with a history of non-organic sexual dysfunction. Otherwise, anxiety does not have an impact on levels of arousal; in fact, it improves it.

The results from studies using the plethysmographic tests seem to be linked to studies carried out in related domains. Subject to empirical confirmation, we can therefore suggest the following cognitive theory concerning the relations between anxiety and arousal: sexual arousal can be regarded as a complex response that requires the convergent interpretation of internal and external stimuli. Anxiety may have different effects on this process, sometimes neutral, sometimes facilitating and sometimes inhibitory.

On the one hand, anxiety can trigger a vegetative emotional reaction that may be associated to a concomitant erotic stimulation. Thus, anxiety facilitates the sexual response: this can be called a *priming effect*. This effect is regularly observed in labs, mainly among women. It likely also works in certain compulsive sexual behaviours or, more commonly, in those numerous persons that report being sexually aroused when stressed.

On the other hand, anxiety can cause a massive irruption of non erotic cues in working memory. Therefore, cognitive function available for treating erotic stimuli is diminished and sexual response is impaired. This is an effect of *cognitive interference*. A trait called *erotophobia* could be regarded as a vulnerability factor to cognitive interference. Erotophobic subjects are characterized by a trend to focus upon danger-related information when they are in a sexual situation and by a higher risk of sexual dysfunction.

Finally, anxiety often increases vigilance. The increase in attention thus obtained may focus on erotic stimuli, therefore reinforcing the priming effect. At the opposite end of the

scale, the gain in attention may also be dedicated to danger signals of no erotic value; under these conditions, it is the interference effect which is reinforced.

REFERENCES

- Adams, A. E., Haynes, S. N. & Brayer, M. A. (1985). Cognitive distraction in female sexual arousal. *Psychophysiology*, 22, 689-696.
- Baddeley, A. D. (1992). Working memory. *Science*, 255, 556-559.
- Baddeley, A. D. & Hitch, G. J. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation*, Vol. 8. New York: Academic Press.
- Bancroft, J., Janssen, E., Strong, D., Carnes, L., Vukadinovic, Z. & Long, J. S. (2003). The relation between mood and sexuality in heterosexual men. *Archives of Sexual Behavior*, 32, 3, 217-230.
- Bancroft, J. & Vukadinovic, Z. (2004). Sexual addiction, sexual compulsivity, sexual impulsivity or what? Toward a theoretical model. *Journal of Sex Research*, 41, 3, 225-234.
- Barlow, D. H., Sakheim, D. & Beck, J. G. (1983). Anxiety increases sexual arousal. *Journal of Abnormal Psychology*, 92, 49-54.
- Beck, J. G., Barlow, D. H., Sakheim, D. K. & Abrahamson, D. H. (1987). Shock threat and sexual arousal: The role of selective attention, thought content, and affective states. *Psychophysiology*, 24, 165-172.
- Bodinger, L., Hermesh, H., Aizenberg, D., Valevski, A., Marom, S., Shiloh, R., Gothelf, D., Zemishlany, Z & Weizman, A. (2002). Sexual function and behaviour in social phobia. *Journal of Clinical Psychiatry*, 63, 10, 874-879.
- Byrne, D. & Schutle, L. (1990). Personality dispositions as mediators of sexual responses. In J. Bancroft, C. M. Davis & D. Weinstein (Eds.), *Annual review of sex research*. Lake Mills, IA: The Society for Scientific Study of Sex.
- Chivers, M. L. (2005). A brief review and discussion of sex differences in the specificity of sexual arousal. *Sexual and Relationship Therapy*, 20, 4, 377-390.
- Damasio, A. (2003). *Looking for Spinoza: Joy, sorrow and the feeling brain*. Harcourt, Inc.
- Dutton, D. G. & Aron, A. P. (1974). Some evidence for heightened sexual attraction under conditions of high anxiety. *Journal of Personality and Social Psychology*, 30, 510-517.
- Elliot, A. N. & O'Donohue, W. T. (1997). The effects of anxiety and distraction on sexual arousal in nonclinical sample of heterosexual women. *Archives of Sexual Behavior*, 26, 6, 607-624.
- Eyzenck, M. W. (1991). Cognitive factors in clinical anxiety: potential relevance to therapy. In M. Briley & S. E. File (Eds.), *New concepts in anxiety*. London: Mac Millan Press.
- Farkas, G. M., Sine, L. F. & Evans, I. M. (1979). The effects of distraction, performance demand, stimulus explicitness and personality on objective and subjective measures of male sexual arousal. *Behaviour Research and Therapy*, 17, 25-32.
- Geer, J. H. & Fuhr, R. (1976). Cognitive factors in sexual arousal: The role of distraction. *Journal of Consulting and Clinical Psychology*, 44, 2, 238-243.
- Hale, V. E. & Strassberg, D. S. (1990). The role of anxiety on sexual arousal. *Archives of Sexual Behavior*, 19, 6, 569-581.

- Hoon, P. W., Wincze, J. P. & Hoon, E. F. (1977). A test of reciprocal inhibition: Are anxiety and sexual arousal mutually inhibitory? *Journal of Abnormal Psychology*, 86, 65-74.
- Kafka, M. P. (2007). Paraphilia-related disorders. The evaluation and treatment of nonparaphilic hypersexuality. In S.R. Leiblum (Ed.), *Principles and practice of sex therapy* (4th ed.), New York: Guilford Press.
- Kaplan, H. S. (1974). *The new sex therapy*. New York: Brunner/Mazel.
- Kapsi, S. P., McNally, R. J. & Amir, N. (1995). Cognitive processing of emotional information in posttraumatic stress disorder. *Cognitive Therapy and Research*, 19, 433-444.
- Kempeneers, P. & Barbier, V. (2008). The influence of anxiety on sexual arousal: Towards a cognitive theory [L'influence de l'anxiété sur l'excitation sexuelle : vers une théorie cognitive]. *Sexologies*, 17, 2.
- Koukounas, E. & McCabe, M. P. (2001). Sexual and emotional variables influencing sexual response to erotica: A psychophysiological investigation. *Archives of Sexual Behavior*, 30, 4, 393-408.
- Lange, J. D., Wincze, J. P., Zwick, W., Feldman, S. & Hugues, P. (1981). Effects of demand for performance, self-monitoring of arousal and increased sympathetic nervous system activity on male erectile response. *Archives of Sexual Behavior*, 10, 443-463.
- Lavy, E. H., Van den Hout, M. & Arntz, A. (1993). Attentional bias and spider phobia: conceptual and clinical issues. *Behaviour Research and Therapy*, 31, 17-24.
- LeDoux, J. (1996). *The emotional brain*. New York: Simon & Schuster.
- Leiblum, S., Seehuus, M., Goldmeier, D. & Brown, C. (2007). Psychological, medical, and pharmacological correlates of persistent genital arousal disorder. *Journal of Sexual Medicine*, 4, 5, 1358-1366.
- Lykins, A. D., Janssen, E. & Graham, C. A. (2006). The relationship between negative mood and sexuality in heterosexual college women and men. *Journal of Sex Research*, 43, 2, 136-143.
- Mandler, G. (1984). *Mind and body. Psychology of emotion and stress*. New York: Norton and Company.
- Marshall, W. L., Laws, D. R. & Barbaree, H. E. (1990). *Handbook of sexual assault: issues, theories and treatment of the offenders*. New York: Plenum Press.
- Martin, M., Horder, P. & Jones, G. V. (1992). Integral bias in naming phobia-related words. *Cognition and Emotion*, 6, 479-486.
- Masters, W. H. & Johnson, V. E. (1970). *Human sexual inadequacy*. Boston: Little Brown.
- Mattia, J. L., Heimberg, R. G. & Hope, D. H. (1993). The revised Stroop colour-naming task in social phobics. *Behaviour Research and Therapy*, 31, 305-313.
- McNally, R. J., English, G. E. & Lipke, H. J. (1993). Assessment of intrusive cognition in PTSD: use of the modified Stroop paradigm. *Journal of Traumatic Stress*, 6, 33-41.
- McNally, R. J., Riemann, B. C. & Kim, E. (1990). Selective processing of threat cues in panic disorders. *Behaviour and Therapy*, 28, 407-412.
- Meana, M. & Nunnick, S. E. (2006). Gender differences in the content of cognitive distraction during sex. *Journal of Sex Research*, 43, 1, 56-67.
- Meston, C. M. & Gorzalka, B. B. (1995). The effect of sympathetic activation following acute exercise on physiological and subjective arousal in women. *Behaviour Research and Therapy*, 33, 651-664.

- Meston, C. M. & Gorzalka, B. B. (1996). The effects of immediate, delayed, and residual sympathetic activation on sexual arousal in women. *Behaviour Research and Therapy*., 34, 143-148.
- Meston, C. M. & Heiman, J. R. (1998). Ephedrine-activated physiological sexual arousal in women. *Archives of General Psychiatry*., 55, 652-656.
- Palace, E. M. & Gorzalka, B. B. (1990). The enhancing effects of anxiety on arousal in sexually dysfunctional and functional women. *Journal of Abnormal Psychology*., 99, 403-411.
- Peretti, C. S. & Ferreri, F. (2004). Anxiété et troubles cognitifs. In M. Ferreri (Ed.), *Anxiété, anxiolytiques et troubles cognitifs*. Paris : Elseivier SAS.
- Purdon, C. & Holdaway, L. (2006). Non-erotic thoughts : content and relation to sexual functioning and sexual satisfaction. *Journal of Sex Research*., 43, 2, 154-162.
- Rellini, A. (2008). Reviw of the empirical evidence for a theorical model to understand the sexual problems of women with a history of child sexual abuse. *Journal of Sexual Medicine*., 5, 1, 31-46.
- Sbrocco, T. & Barlow, D. H. (1996). Conceptualizing the cognitive component of sexual arousal: Implications for sexuality research and treatment. In P.M. Salkovskis (Ed.), *Frontiers of cognitive therapy*. New York: Guilford Press.
- Valins, S. (1972). Persistent affects of information about internal reactions: Ineffectiveness of debriefing. In R. H., London & R. E., Nisbett (Eds.), *The cognitive alteration of feeling states*, Chicago: Aldine.
- Wolchik., S. A., Beggs, V., Wincze, J. P., Sakheim, D. K., Barlow, D. H. & Mavissakalian, M. (1980). The effects of emotional arousal on subsequent sexual arousal in men. *Journal of Abnormal Psychology*., 89, 595-598.
- Wolpe, J. (1958). *Psychotherapy by reciprocal inhibition*. Stanford: Stanford University Press.
- Yerkes, R. M. & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative and Neurological Psychology*., 18, 459-482.

Chapter 10

**LIMITS TO GENERAL EXPERTISE:
A STUDY OF IN- AND OUT-OF-FIELD
GRAPH INTERPRETATION**

Wolff-Michael Roth

University of Victoria,
British Columbia, Canada

ABSTRACT

Graphs are pervasive features in professional science journals, which makes graphing one of (if not the) most important practice (and therefore skill) of professional science. Scientists generally are expected to be experts in graphing. Contrary to this expectation, recent investigations showed that scientists asked to interpret graphs from introductory-level textbooks in their own field did not at all exhibit expert-like behavior. The present study was designed to understand better the nature of graphing practices among professional scientists. I investigated the similarities and differences in scientists' interpretation of structurally identical in-field and out-of-field graphs. Seventeen physicists interpreted 3 graphs that were derived from entry-level university textbooks in ecology—for cross validation purposes, these were the same graphs used in an earlier expert-expert study—and 3 structurally identical graphs from the field of physics. My analyses reveal that the graphing expertise of physicists is limited even within their field. Their graph interpretations are highly idiosyncratic and contingent both within and across content domains.

Common to the interpretive practices on in-field and out-of field graph was that scientists interpreted them according to the purposes of (a) graphing in science in general and (b) those of the graph interpretation interview session specifically. In using varying resources and in experiencing breakdowns, they exhibited considerable differences between in-field and out-of-field graph interpretations.

Working on in-field graphs, they drew on general knowledge and prior experiences from their professional life, whereas in the context of out-of-field graph interpretations, scientists provided verbal equivalents for the visible, surface features of the line graphs and drew on mundane everyday life experiences to explicate them.

INTRODUCTION

Research in the cognitive and learning sciences has tremendously increased our understanding of what it means to be an expert in a domain and how to acquire the characteristics of an expert. Although there are lively debates about how someone acquires the characteristics of an expert, the characteristics themselves largely remain undisputed. In much of the literature concerning expert-novice differences, scientists are shown to exhibit exemplary expertise in comparison with novices, for example, in problem solving, in using representations, in experimentation strategies, and in ecological sorting tasks (e.g., Shafto & Coley, 2003). Graphing is no exception (Larkin & Simon, 1987) and practicing chemists outperformed chemistry students on tasks requiring transformations of graphs into other representations or vice versa (Kozma & Russell, 1997). Because graphing is one of the central practices of professional science at work without which science as such would not exist (Latour, 1987), scientists are assumed to be *general* experts in many of graph-related studies of expertise (Tabachneck-Schijf, Leonardo, & Simon, 1997). But contrary to general expectations about scientists' graphing competencies, recent studies showed that scientists, too, experience difficulties in interpreting graphs, even when these have been culled from introductory, first-year undergraduate-level courses and textbooks in their own field (Roth & Bowen, 2001). Furthermore, statistically reliable differences between the success rates of university-based and public-sector scientists were detected, which led to the hypothesis that performance is due to familiarity rather than to special ability (Roth & Bowen, 2003). Thus, it was shown that eighth-grade students in a learning environment with great family resemblance to research in the natural sciences developed data analysis and representation skills that were significantly better than those of teacher candidates with bachelors and masters degrees in one of the natural sciences (Roth, 1996). It is improbable that scientists, successful in their careers (i.e., publication rates, grants, scholarships or awards), have cognitive deficiencies that lead to their trouble during graph interpretations. To understand and explain scientists' graph-related expertise requires a different method for analyzing how scientists know and learn mathematical representation, and therefore new approaches focus on graphing not as cognitive abilities but as social practice (e.g., Roth & McGinn, 1998). Perhaps more radically still, a cognitive anthropology of graphing focuses both on the cultural and phenomenological dimensions of expertise (Roth, 2003); and such a position has led to a better understanding of the problems scientists experienced in graph-related practices and competencies.

The research presented in this chapter was designed to investigate the nature of scientists' graph interpretation expertise with a special focus on the similarities and differences between in-field and out-of-field graph interpretation practices but keeping constant the affiliation that was a variable in a previous study where the sample consisted about half and half of university and public sector scientists (Roth & Bowen, 2003). In the present study, university-based physicists provided graph interpretations for (a) a set of three graphs from ecology that had been used in the earlier expert-expert study of graphing with ecologists and (b) three structurally equivalent graphs from introductory courses in their own field (physics). I use the same social practice perspective that informed the earlier study, which amalgamates the cultural and phenomenological perspectives, to understand and explain scientists' graphing

expertise especially the limits of this expertise related to graphs issuing from both within and outside their domain.

Previous studies of scientists' graphing (e.g., Roth & Bowen, 2003) were mainly concerned with graphs within the scientific field of the expert participants. If graphing is a general expertise, then we would expect scientist to transfer their practices from one domain to another. In this study, I am concerned with the question of the extent to which graphing expertise goes beyond the boundary of a field. In the extension of existing studies to understand graphing expertise of scientists, the present one was designed to answer the question, "What are the similarities and differences in scientists' interpretation between in-field graph and out-of-field graph?"

BACKGROUND

Graphs and graphing are quintessential aspects of science; without them, science, as we know it today, would not exist (Edgerton, 1985). However, graphs were not used generally in scientific reporting until the XIXth century. In theoretical ecology, for example, the approach of modeling populations by means of graphs emerged as recently as the 1950s (Kingsland, 1995); in physics, although introduced in the 1920, entropy-temperature graphs still are not used widely in the teaching of the field, though such graphs have many advantages over others in modeling and making visible important aspects of thermodynamics (Roth, in press). In scientific and engineering communities, graphs have been used for three major purposes. First, graphs are material objects that constitute and represent other material but natural objects; existing anthropological and sociological studies have shown how the natural objects are translated through hierarchies of inscriptions until ultimately published (Latour, 1993). Second, graphs serve a rhetorical function in scientific communication. They are constructed such that the research results are difficult to question, and if such were the case, the critic would have to spend at least as much effort and resources into producing the critique as it took to produce the original result (Latour, 1987). Third, graphs act as conscription devices that mediate collective scientific activities, both bringing scientists together and constituting a joint focus for their ongoing talk that is conducted both *over* and *about* them (e.g., Ochs, Gonzales, & Jacoby, 1996).

In this study, I adopt a social psychological perspective, which ascertains that all higher cognitive functions are but traces of societal relations: any sign and its use are concretely available in and through participation in societally organized activity (Bakhtin, 1986; Vygotsky, 1986). In this perspective, the focus of research shifts from the analysis of mental structures to the structures of participation in the practices of communities of knowing. Graphs constitute signs and their use is objectively given in society; and any related higher-order mental function can therefore be studied sociologically (Vološinov/Bakhtin, 1973).¹ Graph interpretation practices always occur in social context in which the meanings of graphs are the outcome of negotiations within the collectivity; and interpretations reflect concrete

¹ As I make use of both the French and the English translations of this work, which sometimes differ in substantial ways, I am referencing both authors under which the French version has been published. There is some confusion about the extent to which Bakhtin contributed, although he is the author of the French version of the book. The English version is entirely attributed to Vološinov, though some Anglo-Saxon authors do attribute the book to Bakhtin as well.

(singularized) realizations of general possibilities for saying something about a graph. To analyze graph interpretation as a social practice, this conceptual framework needs a set of components including ongoing concerns, standard practices, material and linguistic resources, and sets of typical breakdowns (Bowen, Roth, & McGinn, 1999).

In this study I take a social psychological framework to analyze the physicists' graph interpretation practice. The standard graph-related practices in physics include such activities as designing experiments for the purpose of producing graphs, constructing graphs from the experimental data, writing articles in which graphs are used as evidence, and interpreting and critiquing graphs that other people produced. Sets of material resources in graphing include axis labels, units, and scales as well as mathematical and statistical software that allow the production and manipulation of graphs. Sets of linguistic resources in physics include mathematical formulas as another formal language to describe the same phenomenon as much as verbal language. Absence of appropriate tools or changing of familiar contexts can lead to breakdown, which is constituted by interruptions of standard practices and slow-downs in the progress of an activity.

RESEARCH DESIGN

This study was designed to better understand the activities in which physicists interpret in-field and out-of field graphs. By investigating the practices of their interpretation both in-field and out-of-field graphs, focusing on the similarities and differences, one might get at the general features of graphing competency and give some suggestions to the educators who want to teach their students the graphing competency in their teaching context.

Participants

A total of 21 (18 male, 3 female) physicists participated in this study, including two individuals who majored in applied mathematics but work in a physics-and-astronomy department. There were 15 professors, one postdoctoral fellow (1 year since PhD), and five PhD students (just graduated; 6 months, 9 months, 2 years, and 2 years from graduation). The professors had obtained their PhD degrees between 6 to 42 years prior to our interviews/think-aloud protocols ($X = 23.25$, $SD = 14.1$ years). All participants had a minimum six years of experience in doing independent research. All but one individual were involved in teaching graduate, undergraduate, or laboratory courses in physics and physics-related department such as astronomy, geophysics, ocean physics, and physical chemistry—thereby keeping constant the variable that led to differences in performance in the Roth and Bowen (2003) study. For purposes unrelated to the present study, four physicists worked in groups of two.

The present study is concerned with the results from the remaining 17 individuals because the independent contributions of collaborating physicists could not be established from the transcripts. An undergraduate research assistant (pseudonym David), with a double major in physics and anthropology, conducted the interviews/think-aloud protocols with the physicists as part of a work term of the cooperative program in which he was enrolled.

For the purposes of the second part of this study, I draw on the interviews conducted with Annemarie, an associate professor in a department of physics and astronomy who had received her PhD more than 30 years prior to our study. She regularly published in academic journals and was acknowledged as an excellent teacher in the science faculty as evidenced by teaching awards. David attended a coop program. Seeking employment and being interested in anthropology, he was hired and trained specifically for eliciting graph interpretations from physicists pertaining to graphs from within and outside their field (i.e., ecology). In his program, he was near the median in terms of achievement. He liked the experience doing social science research so much that he first took courses in qualitative research methods and then changed his major to anthropology.

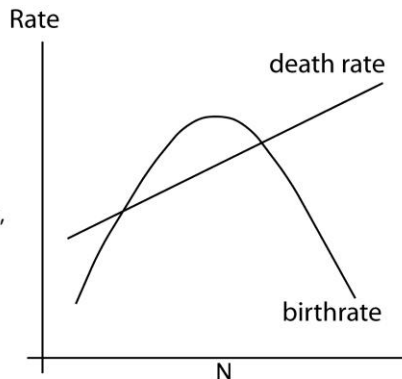
Tasks

In this study, six graphs, three from biology and three from physics were used to compare the interpretation of in-field and out-of-field graphs. The three biology graphs had been employed previously in studies with ecologists (Roth & Bowen, 2001, 2003). These graphs include a distribution, a population dynamics (model), and an isoclines graph typical of those found in introductory first- or second-year undergraduate textbooks in ecology, especially those texts that take a more theoretical perspective. The physics graphs were constructed by a similar method: they were selected and prepared from university-level physics textbooks such that they were (deep-structure) analogues of the biology graphs and were accompanied by a caption that was adapted to the physics content of the graph. (There were some slight surface variations due to the available textbook materials: for example, the biology population graph does not have units on the abscissa, whereas the physics graph has an abscissa label that has concrete numbers on both end of its axis.) For the analogies to be correct, both the structure of the phenomena and their representation had to be similar. Possible graph candidates were photocopied and the appropriate captions were added.

One set of graphs used in the present study featured two curves with “forces” that affect some phenomenon. In the out-of-field case, the task displays birthrate and death rate as functions of population size (density); the two curves intersect twice (Figure 1a). As inscription, the graph constitutes a model of the type that ecologists began using during the 1950s and 1960s (Kingsland, 1995). Birthrate and death rate constitute opposite forces on the population size. A population is in equilibrium when the two forces are equal. The in-field equivalent from physics was created using a mathematical software package based on a dynamical system from classical mechanics (Figure 1b). The graph constitutes the model of a two-dimensional pendulum bob moving above two magnets. There are therefore two forces acting on the bob, one to the left, and the other to the right depending on the bob’s relation with respect to the magnet (magnetic force) and its position with respect to the lowest point of its trajectory (gravitational force). In this pair of tasks, participants were specifically asked to focus on the two intersections of the opposing forces (rates) and the resulting three sections along the abscissa. The correct interpretation identifies the two intersections as an unstable and a stable equilibrium, respectively. Such graphs can be found, for example, in introductory courses dealing with atomic physics, where there are repulsive and attractive electrical forces acting between two atoms. Thus, for example, the Lennard-Jones potential results from two

forces, an attractive force at long ranges (van der Waals force) and a repulsive force that derives from the overlap of electron orbitals (based on the Pauli exclusion principle).

- a. In the logistic model, birthrate and death rate are linear. Let's assume that the birthrate follows a quadratic function (e.g., $b = b_0 + (k_b)N - (k_c)N^2$), such that the birthrate and death rate look like in the figure. Such a function is biologically realistic if, for example, individuals have trouble finding mates when they are at very low density. Discuss the implication of the birth- and death rates in the figure, as regards conservation of such a species. Focus on the birth and death rates at the two intersection points of the lines, and on what happens to population sizes in the zones of population size below, between, and above the intersection



- b. Plot depicting two types of forces on an object. Discuss the implication of the leftward and rightward forces in the figure, as regards to energy. Such functions are realistic if they represent, for example, magnetic and gravitational forces acting on some metallic object. Focus on the rightward and leftward forces at the two intersection points and on what happens to the system in the zones below, between and above the intersection points.

Draw as many implications as possible.

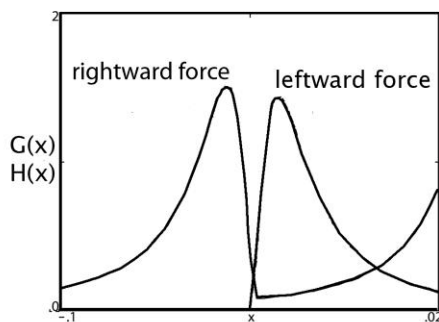


Figure 1. One of the three pairs of graphing tasks featuring an out-of-field and an in-field graph. a. Graph culled from an ecology textbook for teaching stable and unstable equilibrium. b. Graph produced using a mathematical modeling program using a real two-dimensional magnetic pendulum in the Earth's gravitational field.

The second set of graphs featured distributions taken from textbooks in ecology and quantum mechanics, respectively. Whereas in the biology distribution graph, three different types of plant distribution have to be used to make inferences about the differential adaptations to environmental conditions, in the physics distribution graph the different distribution of electron charges in consecutive four s-shells are used to make inferences about the differential ionization energies for each shell (K, L, M, . . .). The caption attached to each graph provided the participants with the associated situation. Thus, in the ecology graph, the participants were informed about the actual study in South Texas that had led to the publication of the results in a journal, from where it was taken and adapted for didactic purposes in textbooks and ecology courses. The task instructs participants to think aloud about the implications that could be drawn from the graph.

The third set of graphs features the interaction of two variables in their effect on a third variable represented in the form of isoclines (lines of equal effect). The three biology isocline graphs represent *essential*, *substitutable*, and *complementary* resources, respectively. The three physics isoclines graphs represent a compressible-gas-to-liquid phase transition, ideal gas, and incompressible-gas-to-solid phase transition. The physics graph was created using a graphics package to produce a contour plot and was representative of thermodynamics graphs

in our collection of physics textbooks featuring the interaction of pressure and volume of a substance at various temperatures.

Collection of Data Sources

The physicists were asked to participate in a graph interpretation session for the purpose of providing expert answers to the selected graphs. Participants were given the following instructions: "Make as many inferences as possible for each of the graphs. Think aloud. If you read text that appears on the page, read it aloud. We are interested in what is going through your mind as you are trying to tell us what you infer." Prior to the graphing sessions, a brief structured interview was conducted to establish biographical background information. All physicists were asked a standard set of questions to find out about the physicist's background. These questions included the time since PhD, how many postdoctoral years they did, how many years they have held a faculty position, the specialty area in which they conduct research, the courses they have typically taught, and the approximate per annum rate of peer-reviewed journal articles they published.

When participants stopped talking during a session, the research assistant was instructed to remind them to talk aloud by asking them to "say what you are thinking right now." (This was not always the case, as shown in the second part of the findings presented here.) The research assistant also tried to avoid answering questions as much as possible, because it was essential to get as much data as possible directly from the participants. (The transcripts provided below both provide evidence for his resistance to respond to queries about the correctness of interpretations and the continued nature of queries from the participants.) Once the physicists stopped interpreting but had not addressed certain salient issues, I had prepared a standard set of pre-formed questions and prompters for the physicists so they would continue to interpret those aspects of the graphs not yet talked about. For example, few physicists addressed the question about where along the abscissa (i.e., for which "N") the increase in the population was largest in the population graph; in these cases, the research assistant asked where the increase in terms of the absolute number of individuals in the population was largest. The participants were instructed to indicate when they had nothing more to say and therefore when they considered being done. In this case, the research assistant asked participants to turn to the next graph. The sessions including all six graph interpretations lasted between 30 and 100 minutes.

Data Sources

To begin with, all interviews were completely transcribed verbatim and, where necessary, video offprints coded according to their temporal position on the tape were inserted into the transcript to show gestures toward particular aspects of the graphs. In a second pass, the VHS videotapes were digitized (Macintosh iMovie); offprint images capturing characteristic moments were created from this software and imported into the transcripts. From all the transcribed interviews, one was randomly selected for close analysis in this chapter. For salient and theoretically interesting episodes, the transcription was improved to contain multiple video images, the length of the pauses, or the overlap between speech and gestures.

In a second moment of analysis, theoretically interesting episodes and entire sessions were digitized and transcribed to include pauses longer than 0.10 seconds, overlapping speech with the interviewer, change in stress and loudness, and so forth (accuracy better than ± 10 milliseconds). At a third level of analysis, the entire sound track of the interview was graphically represented in terms of waveform, speech intensity, and pitch using PRAAT (<http://www.fon.hum.uva.nl/praat/>), a freely available, cross-platform (PC, Macintosh, UNIX) software package for linguistic analyses. Information on these speech parameters were extracted directly from the displays, which were also saved using the relevant software features.

Using Peak™ DV 3.21, which allows the graphical representation of the waveform, pauses in and overlaps of speech were determined and entered into the transcript; this program was also used to coordinate utterances with the video offprints of the situation. Individual utterances were timed with an accuracy of ± 0.001 seconds but rounded to the nearest 10 milliseconds and coordinated with the frames that allowed timing to 33 milliseconds (30 frames/second rate of the VHS video). The sound track was then analyzed for loudness (volume), intensity, and pitch. The complete output of PRAAT was checked and, where it was problematic, pitch was determined manually from the waveform.

Data Analyses

The present analyses are based on the assumption that reasoning is made observable by interaction participants in and as practical, socially structured, and embodied activity (Garfinkel, 1967). For example, by uttering, “Oh, it says a function of population,” Annemarie made available to David surprise and discovery: she declares a form of realization, which we might gloss as, “Oh, until now I have not attended to the fact the text states that birthrate and death rate are functions of population.” In this way, interaction participants continuously made available for one another actions and reasons for why they do what they do. The analyst does not have to assume any evaluation of Annemarie’s state of knowledge. Rather it is how she displayed her putative interpretation as a resource in the ongoing analysis of the graphical material that is significant. In other words, the-topic-of-interpretation is used as resource-for-interpretation. The videotapes, transcripts, and artifacts produced by the observed individuals therefore are natural protocols of the participants’ efforts in communicatively establishing their mutual sense that they made of the task at hand—consisting of both interpreting the graph and making the think-aloud/interview situation happen in a recognizable and scientifically acceptable way. These protocols constituted the materials that were structured, elaborated, and theorized in this study.

This ethnomethodologically informed approach also requires that “the analyst be, with others, in a concerted competence of methods with which to recognize, follow, display, describe, etc., phenomena of order* in local productions of coherent detail” (Garfinkel, 2002, p. 176). As the experience during data analysis showed, it turned out to be an advantage that the author, too, had obtained a graduate degree in physics. For example, when I analyzed the data with a social psychologist colleague (D. Middleton) he differed in the interpretation of the following utterance, in which the research assistant first described a procedure in terms of the subtraction of death from birthrate, then stopped, and re-articulated the procedure in terms of an addition of birthrate and death rate, where the second term is negative. The first way of

relating birthrate and death rate for finding the overall rate of change ($b - d$) is typical in the community of biologists, from which the graphing task was taken, and which is implied in the positive values the death rate takes in the task (Figure 1). (For the transcription conventions used, see the appendix.)

Fragment 1

040 D: well, yeah, if you take, well shall i think i use the half if you take the birth minus the death (.) rate (0.63) `well the birth plus the death which is negative, you are gonna get (0.13) some positive (0.98) growth rate; right?=
 041

Physicists, on the other hand, typically sign negative those rates that decrease the quantity at hand but add the constitutive rates, here this would be $b + d$ where d would be a negative quantity. A correct interpretation—the research assistant David exhibiting knowledge typical of a physicist rather than a biologist—requires familiarity with the practices of physics. My colleague, a social psychologist unfamiliar with the practices within the physics community—or the ecology community that I have studied ethnographically for more than a decade—provided interpretations that were not grounded in and consistent with the standard practices of the field. Once my colleague and I took this knowledge into account, we came to a shared interpretation (provided below).

Following the precepts of interaction analysis (Jordan & Henderson, 1995), I began by taking my data sources to collective analysis sessions, which last about three hours each, and where all the members of my laboratory contribute to working through the tapes in a second-by-second manner. Our collective analysis proceeds in the following way. The researcher at the controls—here this was me—runs the video until someone requested to stop to talk about a feature or episode—usually the episodes have a duration of somewhere between several hundred milliseconds to the order of 10 seconds. The person requesting the stop points out what is salient to him, described and interpreted the episode, and generated hypotheses to be tested in the remainder of the same tape and in the remainder of the database. The other person also provides his description and interpretation. The episode is discussed until all analysts in the room feel that there is nothing more to say about it at the moment—though subsequent periods of writing often turn up additional features, which would be discussed during some future meeting (in the situation with D. Middleton, this often occurred on the following day). In this way, we worked image-by-image through the video and, correspondingly line-by-line through the transcript.

When appropriate—e.g., when there is interactional trouble observable in the video—I hypothesized what might happen next before moving on to confirm or disconfirm the hypothesis. I then spent the following hours writing individual analyses, commented upon, confirmed or disconfirmed in the remainder of the database. I subsequently shared these analyses with laboratory members, especially with those unfamiliar with the dataset, who therefore served as disinterested peers reviewers as a means to increase the consistency and reliability of the analyses. Continuing the analysis, I both generated new hypotheses and categories and, simultaneously, (dis-) confirming existing ones. The results presented in this paper emerged from weeks of intensive analysis.

Analyzing the tapes from a first-time-through perspective assists researchers in avoiding teleological interpretations, whereby the outcomes of interactions are used to give sense to historically earlier interactions. This prevents me from providing sense to the moment of

interaction that none of the participants could have had, because at the moment of their interaction they could not see what the ultimate outcome would be. For example, after having read the problem stem and talking about the graph for a short while, Annemarie turned to David and asked, “Is that right then?” (see below, Fragment 6, turn 33). At the outset, Annemarie, as all participants, would interpret a graph as part of a project that would ultimately lead to the design of instruction of graphs and graphing. She was asked to serve as an expert, and provide her reading of the graphs. But when she asked the question, Annemarie changed the frame. Although she could be seen as the expert on graphing in her own academic domain, Annemarie requested information from the research assistant whether she was right. I understood this as a problematic moment (interactional trouble) for the research assistant (David), for he had to deal with the attempt to change the frame whereby the presumed expert was asking questions rather than the other way around. Depending on the circumstances, I attempted to predict answers to questions such as “How is David getting himself out of this situation?” and “How will David respond to this request?”

LEVELS OF IN-FIELD AND OUT-OF-FIELD PERFORMANCE

Given the predominance of graphs in science and given that graphing is one of the quintessential scientific process skills, one might assume that scientists with PhDs (high publication rates, grants, and awards) would provide correct—acceptable to someone who teaches an introductory course in the discipline—interpretations of graphs taken from introductory textbooks, especially when these are from their own field. My study shows that this is not the case not only across domains but also within the domain. For the first analysis of graph interpretation, I present the levels of physicists’ interpretations of graphs in both fields, physics and ecology, comparing the present to the results of ecologists of a preceding study (Roth & Bowen, 2003).

Their interpretations are compared with the correct standard answers on some aspects of the graph, where standard answers are the kind of interpretations that university professors provide in their teaching about these and similar graphs (Table 1).

Table 1 shows the percentages of the correct, standard answers of physicists both in- and out-of-field. Paired *t*-tests were conducted for each of the three task pairs and evaluated at an alpha level adjusted according to the Bonferroni correction to correct for experiment-wise error rates due to multiple testing (i.e., $\alpha = 0.017$, $\alpha = 0.0033$, and $\alpha = 0.00033$). For the distribution graphs, the scientists did significantly better in the in-field than on the out-of-field task, $t(16) = 7.61$, $p < 0.00033$. There were 76% correct solutions on the in-field graph but no correct solution on the out-of-field graph.

Using the identification of the two equilibrium points as performance measures, there was no statistically detectable difference between in-field and out-of-field performance on the dynamics graphs, $t(16) = 1.32$, $p > .017$. The mean score on all 4 items was $\bar{x} = 1.53$, $SD = 1.37$. Finally, using the correct identifications of the three scenarios as measures, there was no statistically detectable difference between in-field and out-of-field performance on the isocline graphs, $t(16) = 0.80$, $p > 0.017$. The mean score on the 6 items from the in-field and out-of-field graphs was $\bar{x} = 1.35$ (23 correct for 17 physicists), $SD = 1.41$.

Table 1. Frequency of standard answers on the part of the physics compared to the biologists in a previous study

Task	Physicists ($N = 17$)		Biologists ($N = 16$) ¹		
	In-field	Out-of-field	In-field		
			University ($N=8$)	Public Sector ($N=8$)	Total ($N=16$)
<i>Distribution</i>					
Ionization/Adaptation	13 (76%)	0 (0%)	7 (86%)	2 (25%)	9 (56%)
<i>Dynamics</i>					
Unstable Equilibrium	8 (47%)	5 (29%)	8 (100%)	4 (50%)	12 (75%)
Stable Equilibrium	7 (41%)	6 (35%)	7 (86%)	3 (38%)	10 (63%)
Largest increase in N	- -	3 (18%)	1 (13%)	0 (0)	1 (6%)
<i>Isoclines</i>					
Compressible/ Essential	4 (24%)	5 (29%)	6 (75%)	2 (25%)	8 (50%)
Ideal Gas/ Substitutable	4 (24%)	4 (24%)	6 (75%)	2 (25%)	8 (50%)
Incompressible/ Complementary	4 (24%)	2 (12%)	6 (75%)	2 (25%)	8 (50%)
<i>Summary Statistics</i>					
	$X = 6.67$ $SD = 3.73$	$X = 3.71$ $SD = 1.80$	$X = 5.13$ $SD = 1.69$	$X = 1.75$ $SD = 1.81$	

Note 1: The data about the biologists has been culled from Roth and Bowen (2003).

To be able to compare the results of this study with that of my preceding study involving ecologists (Roth & Bowen, 2003), which involved individuals employed at the university and others working in the public sector, the mean performance on all standard answers were compared. For the biologists in the previous study, the university-based scientists tended to be more successful than non-university public sector scientists, $t(14) = 3.88$, $p < .01$, which I attributed to the difference in familiarity with the tasks—professors teaching undergraduate courses are more familiar with these kinds of graphs than public sector scientists not teaching introductory courses. In the present study, the physicists' mean frequencies of correct, standard answers on in-field graphs was not significantly higher than in out-of-field graph interpretation, $t(16) = 2.06$, $p > 0.05$. The in-field graph results of the physicists can be compared with that of university-based biologist group, because all of the physicists held university jobs. The percentages of correct answers in the biologist group tended to be higher than the in-field graph result of the physicist group. The mean frequency of correct solutions for physicists' out-of-field graphs was similar to that of non-university public sector biologists. I present the fuller explications of the physicists' interpretive practices in each task in the following paragraphs.

In the distribution graph pair, the fundamental problem appears to be what many physicists articulate as their lack of the context- and domain-specific knowledge. In the interpretation of the different plant distribution, one of the physicists explained the distribution using “evolution” as explanatory concept (“evolution has been done in such a way that some different plants have evolved to take advantage of a different niche”). Others did not explicitly use expressions such as the *differential adaptation* or the different *photosynthetic mechanisms* for the different types of plants, although all of the university biologists used this theoretical concept. But, for the different ionization energy in each shell distribution, most of physicists (76%) used an appropriate explanation (one that an instructor of an undergraduate course would accept) such as the definition of ionization or the binding energy of the atom. Some of them explicitly noted that the ionization energy cannot be inferred directly from the graph; in this, they articulated domain-related background knowledge that could not be gleaned from the graph itself. However, this kind of interpretation did not appear in the context of physicists’ interpretations of biology graphs.

For the stability of the equilibrium points in the dynamics graph pair (Figure 1), the frequency of the standard correct answer was not significantly different for the in-field graph task. The videotapes show that in their interpretation of the dynamics graph pair, some physicists identified (stable, unstable) equilibriums. In the population dynamics graph, five (29%) physicists identified the unstable equilibrium point correctly and five incorrectly identified it as a stable equilibrium. One correctly identified it following active elicitation by the research assistant and one identified it as unstable using incorrect reasoning. Three physicists gave explanations for the characteristics of the intersection point (e.g., “steady state solutions to the population”) and two did not comment at all. For the stable equilibrium point, six (35%) physicists identified it correctly and one identified it as an unstable equilibrium. One individual identified it correctly after the research assistant intervened, actively requesting an explication; one physicist described it as “convergent point”; and two called it a point of “equilibrium.” Four individuals described the features of the equilibrium point (e.g., “the population is constant”) and two refrained from commenting about the feature. Four physicists correctly identified the stability of both equilibrium points in the population dynamics graph. Three physicists correctly identified the largest increase of the population size as that point in the graph where the function $(b[N]-d[N]) \cdot N$ was maximized; 11 physicists suggested that the maximum increase was where $(b - d) = (b - d)_{\max}$, two thought the maximum was where $b = b_{\max}$, and one pointed to the left intersection as the answer. One of those who mentioned that the largest increase occurs where $(b - d) = (b - d)_{\max}$ explained that the three possible values of $(b - d) = (b - d)_{\max}$ would be at very low N , at very large N , or somewhere in between.

In the physics dynamics graph task (Figure 1b), seven (41%) physicists correctly identified the stable equilibrium, and one of them named it “equilibrium,” and the other called it “neutral equilibrium” (Table 1). Two individuals incorrectly identify it as an unstable equilibrium. Five physicists described the features of the equilibrium point such as “the forces are equal,” “feels no force,” “remains motionless or stationary,” or “oscillates over some range of x ” without, however, identifying the stability of the equilibrium point. One individual did not note any special features concerning the intersection of the two graphs. In sum, therefore, physicists generally were somewhat familiar with the concept of equilibrium: all except one noted some of the features of the intersection points in terms of equilibrium or related concepts, although they did not necessarily comment about the extent of the stability.

Similarly, eight (47%) physicists identified the unstable equilibrium in the physics dynamics graph, one named it “equilibrium,” and another individual wrongly denoted it as a “stable equilibrium.” Four participants described features of the equilibrium point and one call it “a point of inflection”; and two individuals did not comment at all about the unstable equilibrium point. Six physicists noted the stability of both equilibrium points. In sum, therefore, only two physicists identified all the stabilities of equilibrium points in the graphs from both fields.

The third task consisted of triplets of isocline graphs. On both in-field and out-of-field versions, the frequency of correct answers was low ($< 30\%$). One physicist provided the standard correct answer in all of the three biology isoclines graphs consistent with the concepts of “essential,” “substitutable,” and “complementary” resources. Two physicists provided a correct answer in all of the three physics isoclines graphs as the “compressible phase transition,” “ideal gas,” and “incompressible phase transition” cases. No individual provided the correct answer on all of the six isoclines. On average, then, physicists were correct on 2.35 out of the 6 aspects (39%) of the in-field graphs and provided 1.47 standard answers on the 7 aspects (21%) of the out-of-field graphs. In total, this amounted to 3.82 (29%) correct answers on the 13 aspects of interest. The physicists’ success rates on both in-field and out-of-field graphs were similar to the response patterns of public sector scientists in ecology.

DIFFERENCES ACROSS DOMAINS

The physicists’ interpretations of in-field and out-of-field graph differed in many respects. In general, they tended to draw on different types of graphical resources across the pairs of structurally identical tasks. When I began this study, I hypothesized that there might exist some clear patterns in the extent (time, words) to which participants engaged with the tasks across domains. The most dominant pattern was that the physicists spent more time and talked more on in-field graphs than on out-of-field graphs. From the total 51 in-field and out-of-field graph pairs, there were 31 pairs (60.8%) in which the participants spent more time on in-field graphs than on the corresponding out-of-field graph. The videotapes and transcripts revealed an obvious pattern: they talked more (had more to say) about the in-field graph than about the corresponding out-of-field graph. For example, one typical physicist produced more than twice the number of words in his in-field graph interpretation: From the total 7652 words he produced, 5212 words are uttered in in-field graph interpretations whereas 2440 words were related to out-of-field graph interpretations. The distribution of time/words across tasks was not constant, however: for the distribution, dynamics, and isograph sets, he produced 465/1897, 767/1790, and 1208/1525 words. A total of six physicists talked more about in-field graphs across the three tasks.

From a social practice perspective, the resources mobilized during performance are particularly important. Here, I articulate some of the differences in material resources—e.g., axis labels, units, and scales—physicists used for their in-field and out-of-field graph interpretations. In a Cartesian graph the axes constitute important structures that may hinder or facilitate interpretation. In this study, nearly all physicists explicitly articulated the nature of the axes during the beginning stages of each task. There were more variations in out-of-

field graph than in in-field graph in confirming the axis, although there were differences in the degree to which the axes were represented in each task. I exemplify the findings with materials from the distribution graph pair depicted in Figure 1.

In the dynamics graph pair, there are no scales or units on either axis of the biology dynamics graph axis; but there are axis labels “rates” (vertical axis) and “N.” The structurally equivalent task from physics includes concrete numbers on the horizontal axis labeled “x.” On the vertical axis, there are concrete numbers and labels referring to force functions without any other labels or units. These differences are possible mediators for variations across the two tasks. My videotapes show that in their interpretations of the abscissa of the biology dynamics graph, eight physicists asked questions about the nature of “N,” despite the fact that this letter is used in many fields to denote numbers, population sizes, and densities. Four physicists suggested that the letter denoted “population,” one thought of it as population density, one treated it as population size, and one used it as “some [generic] parameter.” Two did not make a comment concerning the nature of the abscissa. One physicist attempted to confirm with the research assistant whether he could assume the two axes to be linear and he wanted to know whether the intersection of abscissa and ordinate identified the true origin of the grid. For the ordinate label “rates,” two physicists made explicit references to it. One physicist furthermore suggested that “rate” had to be associated with particular units and continually referred to the slopes of the curves, to distinguish “rate” (as in “birthrate,” “death rate” from “change of the rate” (as in slope of the two curves). Another physicist tried to express *rate* as a particular number with a particular unit, and using a concrete unit is, to him, a way of making sense:

well, no, to make any sense at all, this [rate] would have to be death rate per ten to the fifth or ten to the fourth per some number of population. Otherwise it wouldn't make sense at all. This would just be per second or per year or per something like radioactive decay, so this death rate to have any sense presumably has to be per some number of the population. Presumably, because one of the population is highest here, I mean this is almost flat, the first approximation except there is no—this is a linear scale, presumably, right?

The double nature of the “rates” involved gave rise to considerable interpretive problems that a number of physicists—including the one featured in the case study below—could not satisfactorily resolve. Thus, the commonly used term “rate” refers to the slope of a function, which in the present case are birthrate and death rate. But because the two functions depend on the variable N , the slopes b' and d' of the functions at any one point are given by the differentials $b' = \partial b / \partial N$ and $d' = \partial d / \partial N$. Each function, however, also is a derivative of the population with respect to time, that is, $b = \partial N^+ / \partial t$ and $d = \partial N / \partial t$. The derivatives of the two functions displayed are therefore $b' = \partial^2 N^+ / \partial N \partial t$ and $d' = \partial^2 N / \partial N \partial t$. It is this double dependence of two rates on time and on the population size (density) that appeared to have been at the origin of the troubles for these physicists.

In the physics dynamics task, the legend of the attractive force functions on the ordinate tended to confuse a number of the physicists. In some instances the research assistant explained in advance that the legend represented two simultaneous plots of force functions. Nearly all participants took the vertical axis to represent forces or force functions. Five used it as a magnitude or strength of the force. Most of the physicists took the “x” on the abscissa as position or location or displacement for granted—which is one of the standard ways in which

distances are denoted in the field, especially in the one-dimensional and two-dimensional cases when the problem does not ask for radial coordinates. One individual asked whether the graph represented the magnitude of the force in time—similar to the interpretation of “N” as time found among biologists (Roth & Bowen, 2003) and related to the problem of understanding “rates” as functions of time. One physicist initially interpreted “x” as denoting the distance between the two forces and then changed repeatedly how he referred to the sign. Seven physicists explicitly talked about the scales or units and two suggested that the scales were “weird.” One physicist expressed himself for an extended period about the fact that the origin of the graph was not in the middle, and finally made the assumption that the center would be the origin (“zero”).

CONTINGENT NATURE OF INTERPRETATION

In this section, I provide a more global picture of the contingent nature of graph interpretation by following several scientists across the different in-field and out-of-field graphs. To get a better understanding of how particular interpretations actually emerged, I provide a detailed case study of the beginning of one graph interpretation session in the subsequent section.

From a social practice, graphs are but material resources that are mobilized in and through agency for the purposes at hand, which are realizations of collective possibilities and motives. Any conscious action inherently is understandable, because human beings have grounds for actions that can be verbally articulated, and language “is a practical consciousness-for-others and, consequently, consciousness-for-myself” (Vygotsky, 1986, p. 256). In this perspective, the relationship of a graph to its interpretive referent, which is a fundamental relation onto which other relations are grafted during interpretations, is the result of social practice and cannot be deduced from a graph independently of the context of its use. More importantly, it is a thing that cannot be detached from the language generally and words particularly, and in this impossibility, it becomes a social phenomenon such that cognition inherently lies inside and outside, at and across the individual | collective boundary: “The word is a thing in our consciousness . . . that is absolutely impossible for one person, but that becomes a reality for two” (p. 256). That is, the interpretations bear all the marks of the sociality of the research session—think aloud protocols/interview sessions—and cannot therefore be taken as evidence of skills independent of this context even though the participants may draw on their prior experiences and knowledge as resources for coping with the present tasks (Roth & Middleton, 2006). I suggest that graph interpretation is not just the result of a deployment of embodied context-independent cognitive skills but that it constitutes a highly contingent and therefore context-dependent practice. (This is so because the dispositions to act and the current field are mutually constitutive: What is perceived is a function of the dispositions and the particulars perceived activate certain dispositions, see Bourdieu, 1990.) In other words, physicists’ graph interpretations are situated in the context of each in-field and out-of-field task and in the interactions with the interviewer and are contingent on the resources the physicists bring with them to the tasks. At the same time, the singular productions in the various sessions realize *collective* possibilities in a concrete way, and therefore are not so singular at all: the verbal productions could not be understood unless

they were already embodied as possibilities on the part of the listener (research assistant) and the analyst (me).

To exhibit how their interpretation is situated in the context of the task, I present several examples selected on heuristic grounds from across tasks. Thus, on the biology distribution graph task, one physicist started his interpretation by looking at the axes and then one-by-one talked about the three elevation-dependent plant distributions. He completed his spontaneous interpretation within three minutes by saying “that’s all about I can say about that particular graph.” It can be seen in the following that he explicitly expressed the correlation between two curves labeled C3 and CAM, although he could not explain further the reason underlying their distribution.

The c-three here seems to be very much uh, important at the higher elevations two thousand and comes down to, to a minimum but it does seem that to uh, increase again at the uh, hottest and driest. So, so it’s a little bit hard to tell exactly uh, whether there is an exact correlation between the elevation and weather, it’s hotter, drier, cooler. So, the reason for the dip in the C-three curve I guess, you know that will require further examination. On the other hand, the CAM plant seems to flourish most best at that elevation where the dip occurs in the c-three curves, so there must be a sort of negative correlation between those two types of plants.

In his biology dynamics graph interpretation, this physicist asked what “N” was while looking at the graph and caption. Before he proceeded to articulate an interpretation each of the three regions defined by the two intersection points, he pointed out the inconsistency between the caption and the form of the graph. The interactions that constitute the meaning of the graph can be seen more dramatically in the biology isoclines graph. He started his commentary with the utterance, “Oh, god! I’m not used to this type of graph. Okay. This is, okay. The amount . . . so I have to learn to interpret these.” He inquired about what the graphs represent through reading the caption repeatedly, pointing out or tracing the related parts on the graph plate with frequent long and short pauses. After 4 ½ minutes and after several failed attempts at producing an interpretation, he finally asked the research assistant guiding questions including “I’m puzzled by exactly what the significance of the graph actually is. You got some questions that might lead me.” With the help of the interviewer’s leading comments, he finally described the problem:

Yeah, okay. But the problem, the problem that I am seeing, I mean, why your trend i-, what, heuh ((sighs)), what your trend is supposed you can see in this particular one is uh, you got two variables and you want a third dimension. Okay, now, that’s a problem, we always have. I would say that a probable, that’s a very common situation physical scientists as you got two, two variables and then you got your function itself, might need a plot things three dimensionally, in physical chemistry, well, what we do this, we, we would plot at a weak view, and then on hell, we’d sketch a third. With the modern uh, graphics package, you can actually plot them in three-dimensions uh, and so what you have to, while you do, but sometimes you reduce them to two dimensions by doing projections. Oh, okay, now, let me see ((6 second pause)) but what, what actually puzzles me in this particular, I haven’t got a clear idea in my own mind as to what, okay, if we’re at a third dimension, what uh, what would we be plotting and what would we be projecting, okay, so, okay.

Although the situation of plotting three dimensionally is very common in his own field of physical chemistry—after all, the p-V-T diagrams used for the in-field representation is a basic element of any introductory course in the field—this physicist expressed experiencing difficulties in forming a clear idea as to what the graph really means. Immediately following this episode, it was in and through the interaction with the research assistant that this physicist was led to plot a three-dimensional graph. Only after drawing this three-dimensional graph changed the situation did the individual come to provide a correct reading for the three cases of biology isoclines. This again shows the extent to which the available *social* resource, the conversation with the research assistant, allowed him to change his reading to one that is accepted in the field. Some readers may think about this event as a weakness of the study, but it turns out that even under the most rigorous control for the contextual factors, interview and survey researchers is marked by the social interactive nature of the data collection process (e.g., Suchman & Jordan, 1990). Even if the researcher were required not to speak at all, we would still have to take into account the orientation of the participant (e.g., Bakhtin, 1986), who is speaking *for* and *to* the researcher, and who uses language that came to him or her *from* the generalized other and, in and through this session, returns to this other.

A similar kind of contingency of the task and interactions among available resources and interviewer can also be found in the in-field graph interpretations. For example, before starting the interpretation of the physics dynamics graph, the physicist had a long discussion with the interviewer about the scale of the abscissa, because there are concrete asymmetrical numbers on both ends of the x-axis. But, in his physics distribution graph, he identified the graph as “density versus distance from the nucleus” from the origin and provided a more detailed identification of the graph (“this is a prediction of the probability density finding an electron at a given distance”). Concerning the physics isoclines graph interpretation, he expressed the family resemblance between the two graphs that made a pair:

Okay, we're back to one of these things again, Okay. But at least we've solved that. Okay. You know we had plot things three dimensionally, okay, so we got Vee-one and Vee-two are two variables plotting um, and then we've got curves again which are gonna be three dimensional projections, okay . . . well, it goes back to the same thing on that plant nutrient basically-

After pointing to the similarity between the two tasks (“we're back to one of these things again”), he talked about the three sets of isoclines in terms of real-world phenomena in his own field, such as ideal gases, incompressible liquids, and compressible liquids. He ascribed to the graph aspects of things that he was familiar with in his everyday life.

On the biology dynamics graph one individual referred to two intersections without explaining stabilities and proceeded to talk about the three regions defined the two intersections. Another physicist began by interpreting the three regions from right to left. In the interpretation of the middle region, he identified two intersections “a” and “b” as stable equilibrium at first, but whereas he explained the population change in the middle region, he caught himself and corrected “b” to be a stable equilibrium and “a” an unstable one. A third individual did not mention the stability of intersections, but merely explained one of the properties of equilibrium: “if the birth and death rates are equal presumably, the population is constant.” A fourth physicist used a particular example of “rats in the cage” in his biology dynamics graph interpretation of the three regions from left to right. He added the general

interpretation in the order of middle, right, and left graph sections. In the interpretation of physics dynamics graph, I analyzed their interpretation structure in similar way as in the biology dynamics graph. For example, a fifth physicist started in the left section and described the properties of particle movement around the left intersection and then unfolded his interpretation of the particle movement according to its initial momentum and starting point. His interpretation did not distinguish the three regions. Another individual divided the graph into two regions: where there is only a rightward force and where the two forces act simultaneously. He described the intersections as a case where the sum of the two forces is zero. He completed his interpretation by talking about the energy of across the three regions. All the other physicists' structure of dynamics graph interpretation can be understood similarly. The interpretations exhibited different structures in the interpretation of the biology and the physics graph. In the biology dynamics graph interpretation, five of them changed the focus in the order of the left, middle, and right sections. Four individuals structured their interpretation in this order: left and right regions, then the intersection points, and then the region between the intersection points.

These results show differences within and between pairs of tasks. No two physicists enacted the same sequence through the different graph regions. Thus, two physicists who took the same sequence of left, center, and right regions in their interpretation, differed in the structural details of their interpretations. A third individual pointed out the two intersection points, did not mention their nature as equilibrium points, and then explained the change of the population by comparing birthrate and death rate in the left and center regions (as defined by the intersections in Figure 1), and evaluated each situation.

She continued to the area to the right of the right intersection, but did so only to compare the birthrates and death rates. She returned to the left section of the graph and talked about the reason of higher death rates in the left section, and then proceeded to the center section of the graph defined by the two intersections. She did express trouble identifying where the population increases. She did not articulate population change in the right section, but she asked the research assistant why the death rate was higher than the birthrate and expressed interest about the biology of that phenomenon.

Another physicist compared the birthrates and death rates in the three sections. He then compared the death rates and birthrates at the two intersections. He talked about the change in population size in the three sections from right to left and finally summarized the population change for left section compared with that of right and center sections.

In sum, then, whereas the performances of the experts sometimes are thought to be more or less homogeneous—the very notions of practice and community of practice suggests commonalities not shared with other practices and communities—this study is consistent with others that find considerable within and between expert performances, some even pointing to the occurrence of better performances by non-experts (e.g., Abel, Lima Silva, Campbell, & De Ros, 2005; Shafto & Coley, 2003). Whereas the results so far pointed out the rather low performance levels and the heterogeneity and contingency of the interpretations, I have yet to focus on the concrete details and relations from which the individual sessions evolved in the dialectic tension between (social, material) resources, which constitute affordances and constraint, and the agency that mobilized them. This is the topic of next section.

THE WORK OF STRUCTURING A GRAPH READING TASK: ANATOMY OF A PROBLEMATIC GRAPH READING

In a previous section, I show that the number of physicists who provide interpretations of entry-level graphs in physics (in-field) and ecology (out-of-field) is rather low. The graphs clearly did not encode 10,000 words of experts but rather constituted unfamiliar and foreign entities that resisted these experienced scientists' efforts in making sense. Or, to put it in a tongue-and-cheek perspective, in many instances even 10,000 words were insufficient to produce graph readings that were consistent with the canon of the field. Existing models of graph interpretation in the field of cognitive science often take cursory descriptions of graph interpretation sessions as their point of departure, thereby failing to take into account the microlevel details of *actual* interpretation sessions that tell us a lot of what *really* rather than possibly happens in the interpretations. How can we get access to what actually happens, as seen by those involved? More poignantly, how can we get access to processes that are invisible—and perhaps compiled—in the performances of experts? That is, I am asking here for how we can access to a life-world perspective that some in artificial intelligence already embody in their modeling efforts (Agre & Horswill, 1997). In some existing cognitive science studies, what experts say (after the fact) that they are doing is taken as fact. Yet there is mounting evidence that what expert scientists, engineers, teachers, and other practitioners say they have done and what they could be seen as doing is often very different (e.g., Bourdieu, 1990). In some social sciences, it has been shown that methods normally hidden from view come to the fore and are mobilized when experts are in trouble, in situations of “breakdown,” when their ordinary ways of functioning no longer work so that in the attempt to accommodate participants exhibit their methods of and for social conduct (Garfinkel, 1967). Rather than observing experts in situations where they provide unproblematic accounts of what they have done, an appropriate research method puts them—often with peers—into situations where they make available all those skills and procedures that really constitute their expertise (e.g., in the control room of the London Underground [Heath & Luff, 2000]).

To show what is salient and how experienced physicists interact with the graphing tasks in my study, I provide an ethnomethodologically and conversation-analytically informed study of the first 7 minutes of one session. Any good model ought to be able to predict both efficient as well as incorrect performances, on the part of experts and non-experts alike. I provide the account in part as a test bed that others may be able to use as a standard for graph interpretation models.

The session concerns the ecology dynamics graph and Annemarie, a 30-year veteran of her department whose teaching skills have been rewarded through university-wide awards. In this session, we see her articulate the difficulty of ordering the display sufficiently for getting a good handle on the problem.

When she eventually began to find an orientation, the resource most salient to her are the slopes of the curves, ultimately leading her to produce an interpretive text that was inconsistent with the scientific norm. She expressed a lot of uncertainty about what she perceived and what she did and, to decrease this uncertainty, she engaged in repeated attempts to receive feedback on her progress—counter to the protocol that she nevertheless had agreed to prior to the session.

“I Can Hardly Absorb What That Means”

As a participant approaches a task, it initially is unstructured, though as soon as the eyes are laid on the sheet, structuring beings to operate and separate out the different parts. The work of structuring the text, however, requires reading, which therefore unfolds in time. As it unfolds in real time, reading has to structure what initially is nothing but a “flat” text—this would be apparent if the text had been read by a text-to-speech program currently available on many computers. It is immediately apparent that the voice is not a human one because the prosodic cues that allows listeners to structure hearing are considerably off normal. Intonation, as made available through the different prosodic parameters, is an important means to structure, for ourselves and for others, any form of text that thereby obtains its meaning (Vološinov/Bakhtin, 1973).

The session pertaining to the population dynamics graph begins when Annemarie changed the sheets in front of her over to the second task featuring the dynamics graph from ecology. At this point, her right hand moves toward the caption, the pen stopping on the top right corner (Figure 2). After several seconds, she asks whether the research assistant wants her to read aloud. From the perspective of conversation analysis, it is a question because the research assistant treated it as such: he responds in the preferred affirmative, “sure, if you’d like to” (turn 002).

Fragment 2

- | | | |
|-----|----|-------------------------------------|
| 001 | A: | do you want me to read it out loud? |
| 002 | D: | sure, if youd like to |

In this situation, Annemarie asks David whether she ought to read aloud although she has been instructed to do so earlier and although she has already done so on the preceding task. At the same time, the question–answer sequence ascertains that Annemarie is familiar with the experimental condition that asked participants to think aloud while providing a reading of the graphing tasks.

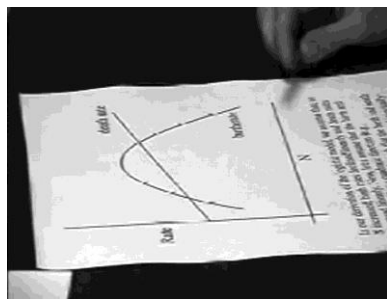


Figure 2. The hand/pen combination moves to the text when the scientists are oriented toward it; but the responsibility for the text always is attributed to the researchers.

Annemarie then goes ahead reading aloud the caption in a stop and go fashion, including long pauses (1.41, 1.33, 1.68, 4.50, 1.74, 1.72, 2.04, and 1.66 seconds), where I heuristically take the one-second rule as a heuristic for denoting something as a long pause: In conversations as well as in school science classrooms, the maximum pauses normally do not

exceed one second (Jefferson, 1989). More so, the voice is strongly modulated, the pitch jumping repeatedly upward, the speech intensity changing from relative piano (low volume) to higher levels, and to points of almost disappearing. This continually changing production of the text in and through the utterance is evident in the following fragment 3 taken from the early part of the session while Annemarie is still reading the caption.

Fragment 3

012 (1.66)
 013 A: <<p>focus on the birth and death rates (0.70) at the two intersection
 points of the lines.> (0.93) and on 'what happens to ^population sizes in the ↑zones of
 population size 'below (0.64) be↑tween an ab↑ove the inter[sec]tion
 014 D: [uum]
 015 A: points.
 016 (1.20)
 017 .HHhssssss. <<f>i can hardly absorb what that means.>
 018 (2.02)

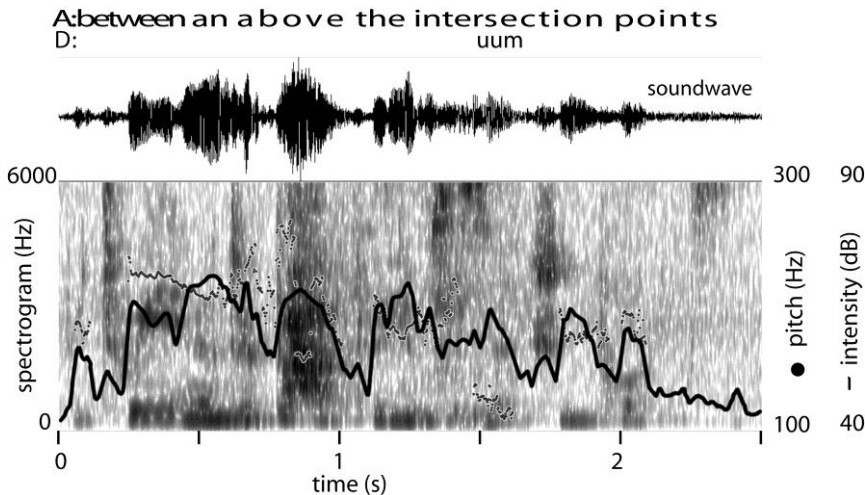


Figure 3. Sound wave, speech intensity, pitch, and spectrogram for a stretch of talk ((turn 013).

As shown in Figure 3, there are considerable variations in several parameters of the prosody, including pitch, speech rate, speech intensity, energy distribution across spectrum, and so on. Because these variations co-occur with the sounds that we hear as words, the latter can be heard with continually changing intonation, emphasizing some words, deemphasizing others, making it clear that the listener is addressed or speaking with such a low volume as if the speech addresses the speaker alone, and so forth. That is, a first level of structure arises in and from the prosodic variations that both lend and constitute differential emphasis to different parts of the text. There are several jumps in the pitch, which can be heard as emphases of the syllable heard. At one point in turn 013, the production of the word overlaps with a break in the voice, resembling a cackle, following which the voice fades away (Figure 3). The figure also shows—in the spectrogram—that there is a sudden shift of the sound energy into higher frequency ranges—as indicated by the dark areas at higher frequency ranges—associated with the cackle and a jump in the pitch to higher values during the

production of the word “above” (turn 13, Figure 3). Finally, the rendering of the utterance above the sound wave shows a change of the delivery rate, as letters come to lie closer or farther away from one another.

Although this is an introductory level graph, Annemarie does not just “rattle off” a reading to produce an interpretation. There are pauses as if Annemarie wants to give herself time “to absorb” the meaning of the words she has just read. Evidence for the pauses is seen in turns 012, 016, and 018. The pauses can be heard and experienced as moments of gathering up. There are other, shorter pauses visible within turns (e.g., turn 013). These pauses punctuate the production of text when Annemarie actually reads. Twice in the fragment, however, Annemarie provides us with evidence of exasperation, which, as she explains, comes from the text that hardly allows her to absorb what it means (turn 017).

The effect of the modulation of the voice parameters is a structuring and commentating. Thus, the increases in intensity, increases in pitch, and changes in the delivery rate can be heard as emphases or de-emphases to the text. The cackle during the production of the word “above” can be heard as a commentary to the reading not directly available in verbal form, but subsequently taken up in the text itself. It is a social evaluation in the concrete utterance unavailable in the text itself but rendered public in and through the intonation (Bakhtin/Medvedev, 1978). Thus, in turn 017, Annemarie comments that she “can hardly absorb what that means,” where “that” refers to the text that she has been reading, a reference further ascertained by the hand position pointing to the caption (Figure 4). We can therefore see in the cackle the growth point of a meta-idea, Annemarie’s understanding of the difficulties she has in understanding what the task as a whole and possibly the text in particular means.² The transcript also shows that the production of the utterance involves intensities much higher than that of the surrounding talk; the intensities move to a low volume (i.e., piano) right after Annemarie returns to the reading of the caption. Here, the piano-level intensity expresses an orientation where she is reading more for herself rather than to the researcher, whereas the normal and higher speech intensities are oriented toward the other.

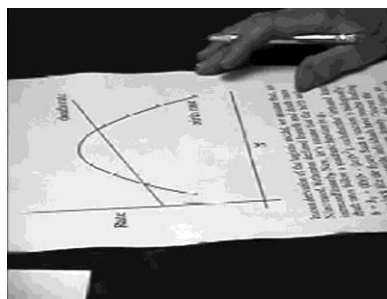


Figure 4. The hand placed near the text exhibits orientation to an aspect of the task that the researcher is responsible for (e.g., Roth & Middleton, 2006).

² In dialectical approaches to psycholinguistics, growth points are whole units that embody meaning but in an underdeveloped, germ-cell-like fashion (McNeill, 2002). As speech unfolds, meaning comes to be more fully articulated by verbal means. Analytically, growth points are identified after the fact by means of backtracking from the fully articulate and evident meaning to the point that there is a first sign for its appearance.

In essence, therefore, the first few moments provide considerable evidence for the work of structuring required in making sense of the task. Annemarie is struggling to impose structure in and through her reading and to articulate an initial interpretation of the caption/instruction. This concern for an understanding of the caption/instruction, which she defines as the “trouble to get out,” is also evident in the moments that follow, as shown in the next section.

“I’m Having Trouble Getting Out”

In the following fragment, we can directly observe the shift associated with an instruction available in the caption, and therefore an orientation toward what the task specifies *her* to do, and therefore, to her domain of responsibility (Roth & Middleton, 2006). Across the turns 019 to 021, we can clearly hear Annemarie reading, and, together with her hand position (Figure 4), understand her to be oriented toward the text. But as she reads the text “focus on the birth- and death rates at the two intersection points” (turn 021), she moves her pencil to the upper (right) intersection point and pauses (Figure 5), which we can see as a shift in her orientation to the task itself.

Fragment 4

- 019 <<pp>discuss the implication of the birth and death rates in the figure as regards conservation of such a species.>
 020 (2.80)
 021 <<pp>focus on the birth and death rates at the two intersection points of the [lines, [(moves pen to upper intersection))
 022 (3.23)
 023 and on what happens to population sizes in the zones of population size below, between, and above the intersection points.>

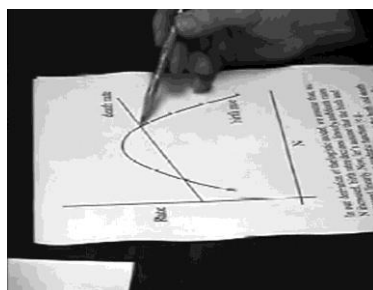


Figure 5. A part of the text (“focus on the birth and death rates at the two intersection points”) turns into an instruction, clearly observable in the .

The fact that Annemarie has changed orientation toward the graph and to the intersection point should be understood not as the mere realization of an instruction, but as a form of behavior the description of which is appropriately described by the instruction (“focus on .”). There are never linear and causal relations between “instructions” (plans), on the one hand, and the situated actions that realize what the instructions (plans) describe, on the other hand (e.g., Suchman, 1987). Rather, the text prospectively configures the behavior without being

able to *determine* it, as we know from other sessions that reading the same text does not cause the participant to orient immediately to this part of the graph. In fact, in numerous instances on my videotapes, the graph interpretations do not deal with the intersections as locations where the graph is sectioned into three areas at all. Whether participants implement the focus on the intersection points therefore is an empirical matter.

A long pause follows (turn 22) before Annemarie continues reading the caption with very low voice intensity but leaving the pen at the intersection (as in Figure 5). At this moment, therefore, there is a double orientation. On the one hand, her gaze has returned to the text, which she continues reading with very low speech intensity, almost inaudibly. (We can hear this also as indicating an orientation to the experimenter, who knows the text, and for whom the text itself therefore does not have to be read.) On the other hand, her pen rests at the intersection point, like a marker of the object about which she is being asked after she has focused on the intersection. That is, the pen continues implementing the focus that she has been asked to enact, or rather, she acts in a way so that we can now say that “focus on the intersection point” is a description of what she has done. In fact, the pen is an embodied pointer to an aspect of the setting, which she does not have to keep in mind and mentally track because both feature and pointer are materially present in the situation where she can find both whenever needed. This dialectical double orientation makes the text to be about the particular aspect of the graph.

Annemarie is still focusing on the text that is asking her to focus on the intersection points and “on what happens to population sizes in the zones of population size below, between, and above the intersection points” (turn 023). In this instance, as she is reading the end of the text, the pen moves repeatedly vertically up and down (Figure 6). That is, here we have a text and a gesture produced simultaneously, which therefore can be seen and heard as part of the same meaning unit (McNeill, 2002). However, this meaning unit, if it denotes a vertical direction for “below, between, and above the intersection points” is not that intended by the instructor of the course from which the graph was culled or by other instructors using the particular graph. The “correct” interpretation of the prepositions is a left-right orientation on the graph, which corresponds to increases and decreases in the population sizes (densities) denoted by the letter *N* on the abscissa. Here, the instruction and the situated action no longer overlap, at least for this very instance at which the pen moves vertically while the words “below, between, and above” are being uttered. There is therefore both a dialectical, inner contradiction between text and gesture, on the one hand, and a logical contradiction between the spatial relations denoted in the text and that denoted by the gesture, on the other hand.

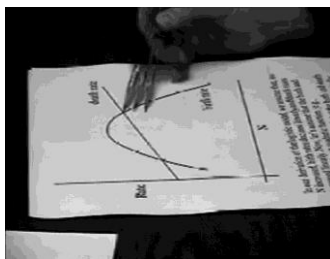


Figure 6. The instruction “below, between, and above the intersection points” is associated with a repeated vertical movement of the pen.

In the long pause that follows (16.37 s), the pen enacts the vertical up-down movement for a second time (as in Figure 6). She appears confused. As Fragment 5 shows, after a 11-second pause, Annemarie moves the hand with the pen downward to the text where she places the pen tip to the right of the first paragraph and the left hand to its left (Figure 7). She has oriented from the graph to the text, apparently seeking further assistance, and then asks the research assistant a question about the text.

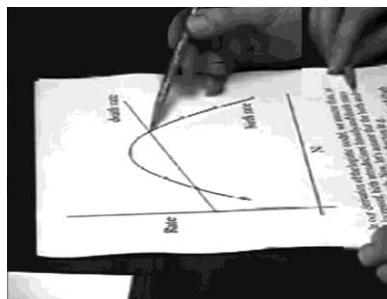


Figure 7. This overlay of two offprints shows how, after pausing to speak for a while and oriented toward the graph, Annemarie returns to the text, a shift in orientation flagged by the change in hand/pen positions.

Fragment 5

- 023 and on what happens to population sizes in the zones of population size below, between, and above the intersection points.>
- 024 (16.37) ((after 11 s, the hands move from the graph to the text [Figure 7]))
- 025 so the first sentence <<p>is not (0.20) relevant to this right? (0.20) i=am> i=m having trouble (0.15) n::='GETting ^out ((movement along text with pencil)) (0.37). <<pp>as long as> i need it further away. (0.47) ((Literally moving paper further away.)) .hhh whats here?

In asking the research assistant about the relevance of the text, Annemarie clearly attributes the responsibility for it to him, a pattern found across the database (Roth & Middleton, 2006). There is text, but, in her assessment, it is not relevant to the task itself. If it is indeed irrelevant, then it constitutes either bad practice or—because all social action is considered to be driven by motives—a deliberate distracter used in a task designed for psychological research purposes rather than reflecting the authentic practices of science. That is, in these particular situations, it appears legitimate to ask questions, as the queries pertain to the caption below the graph to be interpreted, and this text also contains the instructions. When the text generally and the instructions specifically do not appear to be clear, queries are frequently oriented to the research assistant and not treated as illegitimate to the think-aloud protocol described to the participants beforehand. In this instance, the query is followed by a statement about the task in progress “I’m having trouble getting out,” where a particular emphasis is placed prosodically on the “getting” and a somewhat smaller emphasis on the “out.” Annemarie then suggests that she needs “it further away” and then moves the task sheet away from her and lifts it off the table (Figure 8). That is, she literally moves away from the text in an attempt to get out of it, metaphorically speaking, acquire some distance, and, perhaps, approach it in a new way from the distance gained.

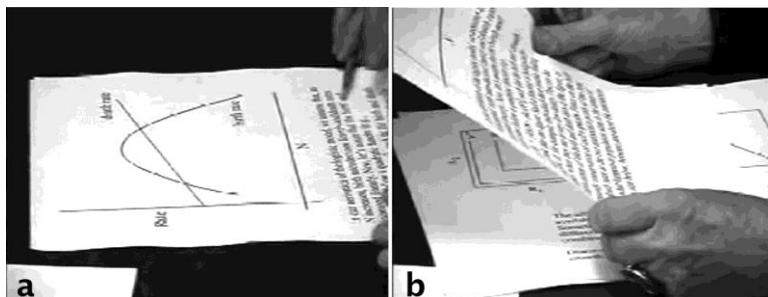


Figure 8. Annemarie formulates that she needs the paper “further away” to overcome her “trouble getting out.” a. This overlay shows how she moves the hand/pen downward while uttering “getting out.” b. She moves task sheet away and lifts it off the table.

Here Annemarie articulates “having trouble getting out,” while her hand is next to the text. The responsibility for the text is that of the researcher (Roth & Middleton, 2006), and the responsibility for the difficulties therefore are rested with the researcher—as this and other studies have shown where the graphs were denoted as bad, poorly designed, and other negative adjectives by scientists from the discipline of ecology (Roth & Bowen, 2003). Responsibility for the trouble thereby is transferred at least partially to the researcher, who had constructed this text that Annemarie “can hardly absorb what it means” (turn 017) and from which she “has trouble getting out.” Eventually, however, Annemarie orients to the task as she perceives it; and here, as the next section shows, what is most salient to her are the slopes of the two curves rather than their heights, as required for a correct interpretation of the graph.

Focusing on Slopes: “Is That Right Then?”

After another long pause (17.42 s), during which she stares at the paper, Annemarie re-reads part of the text and then, by means of a much louder and heard as a resolute “So,” begins a reading of the graph itself. She places the task sheet on the desk and begins to gesture with her pen over different parts of the graph and then with uttering “death rate” (turn 031), articulates a first description of the graph, “death rate increasing and the birthrate increasing and the birthrate is increasing faster than the death rate” (turn 031). As she speaks about the death rate and birthrates, she moves the tip of the pen along the corresponding lines across the left intersection point (Figure 9).

Fragment 6

- 029 ↑here ((pencil to the graph)) (.) we have the
 030 (2.07)
 031 death rate increasing (0.69) and the birth rate increasing and the birthrate is increasing (0.57) faster (0.95) than the death rate.
 032 (1.71)
 033 so they=re both increasing but the birthrate invar is faster increasing than the death rate so presumably that means that the population is increasing. (0.93) is that right then?

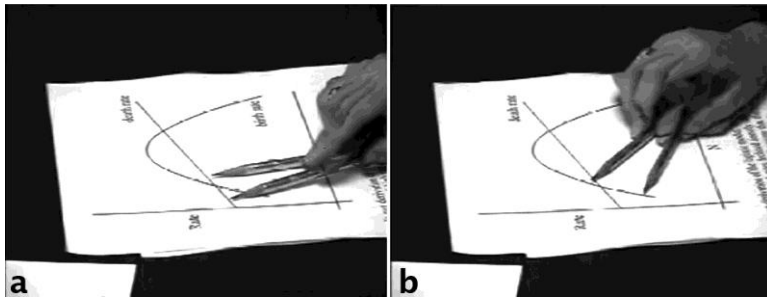


Figure 9. As she describes the behavior of the two curves, Annemarie moves the pen along the line currently being talked about. a. The pen moves with the utterance “Death rate increasing.” b. The pen moves after Annemarie verbally articulates “birthrate is” and while she utters “increasing.”

In this instance, it is apparent that what is salient to Annemarie are the slopes of the two curves rather than their heights; and her pen movement suggests that this salience occurs across the intersection point. That is, she does not act as experts have been described to act in this type of graph. Thus, in economy, the corresponding graph would show an intersection of supply and demand curves with an equilibrium situation around the intersection. According to an existing study of graphs with equilibrium points at intersections, experts do not focus on and interpret the slopes but rather the relative values of the curves on either side of the intersection point (Tabachneck-Schijf et al., 1997).³ In fact, in the supply-demand graphs, experts apparently compare the two curves above and below the intersection point *with respect to the ordinate*, whereas in ecology—despite the influence economic models have had on its theories and graphical models (Kingsland, 1995)—the two curves are compared above and below the intersection point *with respect to the abscissa*. In the present instance, it is not only the verbal text that describes the curve as increasing, but the gesture with the pen tip following the two curves also enacts the observable increase as the hand and gaze moves from left to right (Figure 9).

After a pause, Annemarie resumes by first summarizing, “so they are both increasing but the birthrate is faster increasing than the death rate,” and then states the conclusion, “so presumably that means that the population is increasing.” We note the hesitancy, “presumably that means,” which allows the inference to stand provisionally rather than making it an established fact. Indeed, Annemarie is uncertain about the conclusion and, counter the experimental condition that asked her to think aloud until she has reached her conclusions, she asks the experimenter to provide her with feedback, “Is that right then?” (turn 033).

At this point, then, her conclusions are unexpected. Annemarie clearly has pointed to the two graphs as increasing *across* the intersection and has described both graphs as *increasing*, though the birthrate is increasing *faster* than the death rate. The inference she draws from the “faster” increase is that the population is increasing, which, as a quick comparison of birthrate and death rate to the left of the intersection shows, is not the case: here, the population would be decreasing because the latter exceeds the former. We may ask at this point, “Will Annemarie recover from this error?” and “Will there be further evidence for the fact that the slope of the curve rather than the relative heights of the curve to the left and right of the

³ The economist does not interpret the supply-demand graph (see below) by comparing the relative heights of the curves to the left and right of the intersection but rather compares the graphs on ordinate values above and below the intersection.

intersection are salient in and to her perception?” Cognitive models are only good if they are predictive, and the CaMeRa model proposed elsewhere suggests that “experts” perceive the relative heights rather than the slopes in curves such as the ones presented here (Tabachneck-Schijf et al., 1997). If the CaMeRa model only predicts the behavior of the one expert who constituted the test case, then it is even more limited as it would not describe expertise in general. In particular, the CaMeRa model does not specify why the economy expert focuses on the comparisons of the two curves with respect to the ordinate, whereas the experts in other disciplines focus on the comparison of the two curves with respect to the abscissa. Thus, there appears to be a difference not only between the economist in the Tabachneck-Schijf et al. study and the ecologists in my own previous study (Roth & Bowen, 2003), but the same difference exists with respect to the physicists in the present study, as the latter also tended to compare the two graphs in the left-right rather than up-down directions. Pertaining to the directionality, we may further ask whether Annemarie will continue to treat the left and right of the intersections indistinctly or whether she will distinguish the two sides. The brief exchange with the research assistant that followed her query provides further evidence of what she perceived.

As the beginning of Fragment 7 shows, there is a pause. Then the research assistant harrumphs. There is another pause, which Annemarie breaks by uttering with a rising intonation toward the end, “round this region” (turn 037), during which the research assistant harrumphs a second time. There is another pause, and then David begins to speak (turn 040). He first talks about subtracting the death rate from the birthrate, then about adding the death rate, which is negative, to the birthrate, which yields “some positive . . . growth rate” (turn 040). (Signing quantities such as death rate negatively and adding them to other, positively signed quantities is an approach characteristic of the physics culture in which both the research assistant and the research participant are part.)

Fragment 7

- 034 (0.88)
 035 D: hhum
 036 (0.43)
 037 A: round [this] region?
 038 D: [khmm]
 039 (0.73)
 040 D: well, yeah, if you take, well shall i think i use the half if you take the birth minus the death (.) rate (0.63) `well the birth plus the death (.) rate which is negative, you are gonna get (0.13) some positive (0.98) growth rate; right?=
 041 A: =^yea ^[i=]m looking at the slopes of the curve[ss].
 042 D: <<p>[so]> [uh]=<<p>okay.>

Following David’s description of the general procedure, subtracting or adding the two rates to get their combined effect as the growth rate, Annemarie responds that she is “looking at the slopes of the curves” (turn 041). Here there is a contrast between David’s description of the subtraction/addition of the two curves, which requires the subtraction/addition on a point-by-point fashion, Annemarie’s utterance juxtaposes the consideration of slopes. In her utterance, the personal pronoun and verb, “I’m,” are emphasized, setting what she has been doing in contrast with what David has been describing—if she had heard David say what she has been doing, she would not have needed to repeat it, even if in other words. David’s

subsequent production realizes the preceding utterance as a description different from what he has described, “uh okay,” which can be heard as an “okay, I understand what you are doing.” So in this situation, Annemarie explicitly points again to the fact that *she* is looking at the slopes rather than at the heights of the curves, and she is setting *her* approach against that which David describes—the one in which birthrates and death rates are added/subtracted. There is further evidence throughout the transcript that confirms Annemarie’s continued focus on the slopes. Thus, as shown in Figure 10, there are repeated occasions where she holds the pen along the slope, indicating its slope rather than the height at a particular position, where it has to be compared to the height of the birthrate curve. This comes dramatically to the fore in a subsequent instance further analyzed below.

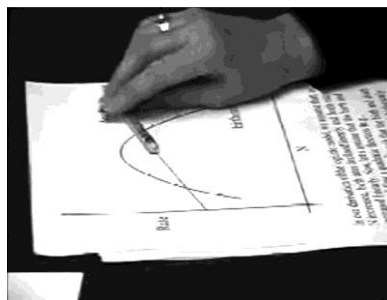


Figure 10. Annemarie repeatedly laid the pen parallel to the slope, showing and constituting her focus on the slopes all the while talking about heights of the curves.

In this situation, we also see how the think-aloud protocol has been changed to another type of situation in which the research assistant actually provides feedback when queried repeatedly, whereas feedback was to be given only after the session. But both research assistant and research participant collude to make the event emerge in this particular way. In fact, in the course of this part of the session concerning the population dynamics graph, Annemarie will continue to ask for feedback, as it becomes apparent that she struggles with making sense. Allowing the session to unfold in this way accommodates the participant and a possible loss of face in this encounter that places her opposite an undergraduate student from her own department, who apparently knows more about the graph than she does. Clearly, the change in situation from a pure think-aloud protocol without any clarifying query–answer sequence to one in which question–answers are accepted as part of the process is a decision achieved collectively requiring the collusion of both.⁴

From the point of view of the conversation, which is a *social* phenomenon *sui generis*, the utterances cannot be understood in terms of and reconstructed from the *independent* contributions of two speakers. Each utterance presupposes and waits for signs of the effect of the speech act in and from the mutual other *for whom* the utterance has been produced (Suchman, 1987). There is therefore an interlacing of utterances so that they can be understood only as irreducible and mutually constitutive: Each utterance *implies* both the one it succeeds and the one that it precedes. That is, a conversation has to be modeled as a transactional phenomenon, where the contributions uttered by the participants are

⁴ In this particular instance, Annemarie and David eventually change the session into one where the latter comes to tutor the former in providing a standard correct reading. The analysis of the particulars of this tutoring session have been provided elsewhere (Roth & Middleton, 2006).

interdependent (Bakhtin, 1986). The *conversation* therefore constitutes the unit of analysis so that the utterance “Am I right then?” cannot be treated as a question until the next turn, which exhibits the effect part of the speech act as a whole. Cognition, expressed in conversation, therefore cannot be reduced to the individual but, inherently, implies shared consciousness and the sociality of cognition .

Some cognitive scientists may consider this situation to be a main problem for the field. But this is not so at all. Cognitive scientists with a social penchant, as any social psychologist, find their data not within “but entirely and completely *without*—in the word, the gesture, the act. There is nothing left unexpressed in it, nothing ‘inner’ about it—it is wholly on the outside, wholly brought out in exchanges, wholly taken up in material, above all in the material of the word” (Vološinov/Bakhtin, 1973, p. 19). Everything psychological exists and is learned in the real processes of communication and verbal interaction; and *society is in the mind* precisely because mind is materially found in society. Thus, we can read the transcript from turn 033 to turn 040 as a request for feedback, which, when it does not come forth, is further specified as to the exact location on the graph to which the query corresponds, before David’s utterance reifies the utterance and its clarification as a question. That is, we can read the transaction as a persistent query and the initial reaction as hesitation; the persistence pays off, as David responds in an acquiescent manner. But this gloss is possible only from hindsight.

“Am I on the Right Track?”: Further Evidence for Focusing on Slopes

The salience of the slopes in and to Annemarie’s perception is further accentuated in Fragment 8, where she summarizes what happens to the population in the right part of the graph. Annemarie is in the process of summarizing the trend that as the birthrate is increasing *faster* than the death rate is increasing” (turns 110–114), “the population is in good shape” (turn 116). The production in this case is not quick, and Annemarie continues to pause frequently, as she has done throughout, in producing this summary. Her right hand moves the pencil tip along the birthrate curve as she articulates the salient feature, “increasing *faster* than the death rate is increasing” (Figure 11).

Fragment 8

- | | |
|-----|---|
| 106 | A: well it just— |
| 107 | (1.18) |
| 108 | feels that as long as the |
| 109 | (1.17) |
| 110 | um birthrate |
| 111 | (4.90) |
| 112 | is increasing |
| 113 | (1.15) |
| 114 | faster than the death rate is increasing |
| 115 | (1.23) |
| 116 | then the population is in (0.15) good ↑shape. (0.86) but when the birthrate begins to decline |
| 117 | (1.98) |
| 118 | and the death rate stays the same ((pencil aligned with the death rate curve))
((pause, pencil comes to left of intersection 2)) |

- 119 (3.55)
 120 its okay for a while but eventually– clearly the ah (0.85) clearly the uh::
 121 (1.14)
 122 population is going to diminish. ↑am I on the right ~track ((rH on paper near
 text))
 123 (2.02)

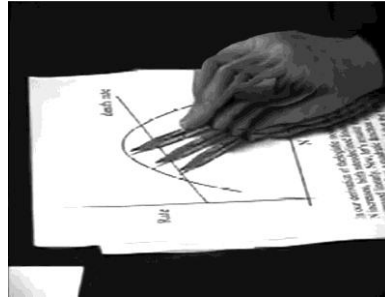


Figure 11. This overlay of three offprints shows the gesture produced simultaneously with the utterance “As long as the birthrate is increasing faster than the death rate, then the population is in good shape.”

This description of a population in good shape changes, however, as the pencil tip moves across the maximum of the birthrate curve (Figure 12a), a section that Annemarie articulates as one where “the birthrate begins to decline” (turn 116). There is a pause, followed by a statement that “the death rate stays the same” (turn 118). While she utters the description, she places the pencil parallel to the death rate graph (Figure 12b). As long (“for a while”) as the birthrate is above the death rate, “it’s okay” (turn 120), but when the birthrate lies below the death rate, then the “population is going to diminish” (turn 122).

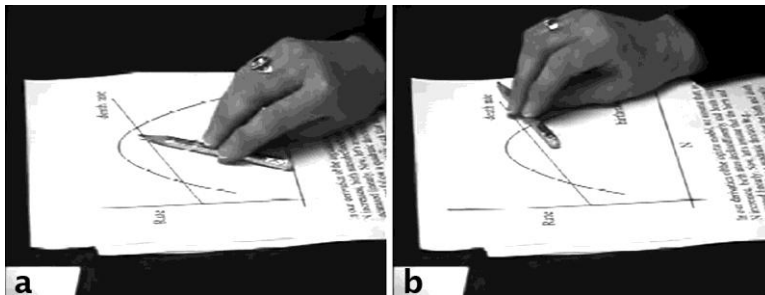


Figure 12. a. “When the birthrate begins to decline . . .” b. “And the death rate stays the same.”

In this situation, it is clear once again that Annemarie perceives and describes the slopes of the curves, which are the givens in her reasoning about what happens to the population of which the curves at hand constitute the birthrates and death rates. Annemarie is not just talking about the birthrate and death rate, but about the birthrate as “increasing faster” than the death rate in the area, as shown by her pencil, where both curves have positive slopes and the former being larger than the latter. She describes the situation to the right of the birthrate maximum as one in which “the birthrate begins to decline” (turn 116) while “the death rate stays the same” (turn 118). Here, clearly, going from the left to the right, the death rate increases for increasing N , whereas Annemarie perceives something that stays constant,

something literally *aligned* with the pencil held closely to the death rate curve in the region that she currently talks about (Figure 12b).

In Annemarie's talk, there is apparent a temporal dimension from left to right in the graph. That is, she does not take the graph to be a representation of birthrates and death rates as a function of the population (density). Thus, moving from left to right, she utters temporal terms: "as long as" (turn 108), "for a while" and "eventually" (turn 120), "begins to decline" (turn 116), and "is going to" (turn 122). Later in the session it becomes apparent that she treats the curves as if they were plotted against time so that going from left to right means a progression of the population in time rather than a plot of birthrate and death rate against the population (density). Neither here nor elsewhere in the session does Annemarie continue by suggesting that the population—when it is to the right of the right intersection point—would decrease and move toward the intersection point. Rather, as indicated here, the "population is going to diminish" (turn 122), which she later articulates as becoming extinguished. She also suggests that in this region, "your total number is going to be on a decline which will be difficult to recover from because the slop of this curve is quite steep at this point."

Here again, as throughout the transcript, there is uncertainty apparent in Annemarie's talk. She does not make definite statements but frames what she says for example as "it just feels that" and toward the end, she asks for feedback on whether she is "on the right track" (turn 123). There are also pauses and repetitions, such as from turn 119 to turn 122, where she both states that something is "clearly" the case all the while it takes repeated attempts to make the statement forthcoming. She is uncertain about what she has done and how it compares to the standard answer, which the research assistant is presupposed to know, as evident from the very fact that he is asked whether what she has said is right.

In summary, then, in contrast to the claims made in the literature about expertise, the scientists in this study generally, exemplified here by the data concerning Annemarie, were far from fluent in the production of their readings; and, more often than not, they made inferences and derived conclusions that professors and instructors of introductory level courses in physics and ecology would not have accepted as correct. Some readers may be tempted to claim that at least some of the participants in this project clearly were not experts. But this is contrary to those who claim (e.g., Linn, Layman, & Nachmias, 1987) that graphing is one of the core scientific process skills and that one would expect a scientists to be able to read a graph that students in introductory courses of their own discipline are expected to provide correct explanations of.

CORE PRACTITIONERS AND LIMITED NATURE OF EXPERTISE

This study was designed to investigate the nature of scientists' graph interpretation expertise, especially the limits of this expertise related to graphs issuing from both within and outside their domain. A study concerning expert graphing in a leading cognitive science journal suggested that experts would be reading dynamic equilibrium graphs such as the one presented here or those in economics (Figure 13) in the following way.

This [supply and demand line] has been stored in the expert's mental image (visual buffer). . . . The expert wishes to explain why the price, if it were currently above the equilibrium price, would be driven down to that price. He does this by considering (in a

pictorial representation) a higher price, showing that at this price there would be a surplus (greater supply than demand), and then reasons verbally that the price would decline. Thus, he uses both pictorial and verbal representations in this explanation. (Tabachneck-Schijf et al., 2007, p. 321)

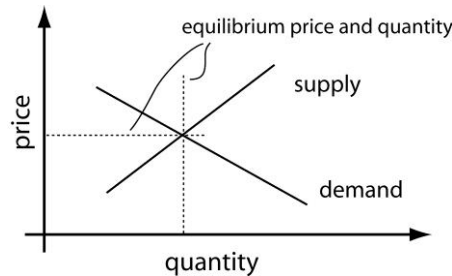


Figure 13. Fundamental laws in microeconomics that relate producer supply and consumer demand are of the same dynamic nature as birthrates and death rates are for populations.

The present study shows that with respect to the graph featuring the two dynamic equilibriums, 47% and 41% of the physicists have been able to identify the unstable and stable equilibriums, respectively, in the in-field graph situation; in the out-of-field situation, the rates were 29% and 35%. Although the reasons varied across individuals, the physicists generally did not talk about the graphs as dynamic situations in the way that the economist did in the Tabachneck-Schijf et al. study. More so, the physicists in the present study, in the same way as the ecologists in a previous study (Roth & Bowen, 2003), analyzed the dynamics in terms of difference in the two curves to the left and right (horizontally above and below) of the intersection point; whereas the economist expert compared the two curves vertically above and below the intersection point. It is evident that their inferences came from perceptions that are different than those postulated for experts in the cited study. And the perceptions are in part driven by the cultural expectations rather than by some form of raw perception taking in by the eye that acts like a *camera*. More so, as the detailed example of Annemarie shows, there is no evidence for any of the processes described to occur in the CaMeRa model, including as to what is being stored in mind and what is not. Thus, for example, whenever this study shows that whenever Annemarie needed to access visual information, she oriented toward the required aspect. Even when she was merely indexing a part of the graph, she did not do so mentally—there is no sign even in my second-to-second and frame-by-frame approach—but physically, keeping her pencil right on the feature that she kept track of. Rather than stating that the population (N) would decline in the region of the graph where death rate curve lies above the birthrate curve and then moves left to the next equilibrium point, those physicists who did not produce the standard correct answers took the graph as implying a crash of the population. Whereas this is the case for the left equilibrium, we need to be cautious with our interpretation about the actual model that the participants expressed. Thus, to the left of the lower equilibrium, the dynamic and the static model lead to the same implication: the population crashes. To the right of the right equilibrium, however, the population declines but only until it reaches the equilibrium (to which, if it overshoots, it will return). However, the scientists who did not infer the equilibrium generally stated that the population, once in this region, would crash. That is, many scientists in this study did not see

the intersections as equilibrium points whereas this is the starting point for the CaMeRa model.

The graph reading expertise of scientists is limited even within their field but, in some instances, even more so when scientists are asked to interpret graphs from outside their field. In this study, scientists interpreted in-field and out-of-field graphs in an experimental setting rather than at work. This type of setting is regularly used in studies where scientists serve as an expert reference group to be compared with novices. Experts not only are assumed to be capable of successfully completing tasks in their own domain but also to have a capacity for transferring skills between domains. (For a critique of the assumption that experts transfer, see Lave [1988].) The present study does not support the notions (a) that graph reading/interpreting is a general scientific process skill and (b) that experts (easily) transfer skills to other fields. Interestingly, however, this study may lend support to another one conducted in the discipline of petroleum science where novices, intermediate experts, and full experts were asked to interpret images of rocks (Abel et al., 2005). In that study, there was gap between the explanations experts gave when explaining their discipline and what they said when making decisions in their discipline. When they described rocks or explain their discipline, they appeared to employ precise vocabulary, whereas they were not able to articulate even semi-formal justifications for their interpretations of petrographic representations. Although the present study did not ask the experts to explain their domains, there, too, appeared to be a gap between what the physicists teach in their courses and what they expect their students to know, on the one hand, and the explanations that they provided when working on tasks taken from undergraduate courses, on the other hand. However, such an interpretation would run counter to that provided in my previous study, where university scientists who also taught undergraduates by far outperformed equally prepared non-university scientists.

The physicists' interpretive practices in this study were far from those that one would expect experts to exhibit, as my participants frequently provided no more than literal readings and failed to perform standard interpretive practices even on in-field graphing tasks but especially on out-of field graphing tasks. We are confronted with these results despite the following aspects that should have made it easy for them to produce standard (correct) interpretations. First, the graphs in this study are similar to those that one can find in typical undergraduate courses of physics and ecology. Second, each pair of physics and ecology graphs has structural similarities in their surface and deep structure, a fact that should have facilitated transfer. This study shows that graphing (graph interpretation) cannot be assumed to be a general scientific process. Rather, it is a social practice employed for achieving specific purposes in particular contexts. My work shows that the scientists exhibited somewhat greater ease with in-field graphs than with the out-of-field graphs.

This study exhibits the contingent nature of graph interpretation even among those who might be considered to be experts with respect to core procedural knowledge in the science. This contingent nature of graph interpretation exists for both in-field and out-of-field graphs. We also find that the points or features in a graph that become salient cannot be determined a priori but rather emerge from the context of the task. For example, in dynamics graph interpretation, almost all of them (15 in biology dynamics graph and 14 in physics dynamics graph) mentioned the intersections. On the other hand, in the distribution graph interpretation, none of them attended to the intersections, although there were many intersections between the different plant and electron distribution graphs. The flow of the focus changes of their interpretation differed from person to person within a task, which also made evident the

contingent nature of their interpretation practice. The function of the ongoing purpose, which is a determinant of a social practice, appears to be common across domains.

When participants interpreted a graph, they drew on available material resources, including axis labels, units, and scales. This study shows, however, that we do not know a priori which of these resources any individual scientist will be drawing on, and, as the case of Annemarie showed, two aspects might be interfering. We therefore need to conduct our studies concerning expertise very carefully, making sure that we ascertain what the actual structures are that are salient to the participant, which in some instances may actually involve contradictory uses of one and the same resource. There were differences between in-field and out-of-field graphing tasks; more questioning and variations of interpretation occurs in out-of-field than in-field graph while they access these material resources. For example, the physicists spontaneously revealed their background knowledge related to the axis labels in the physics distribution graph (e.g., Bohr radius, distance from the nucleus), even though these are not mentioned in the graph or caption. None of them asked about what the axis label “x” is in physics dynamics graph, but in population dynamics graph, many of them asked about the meaning of “N”—despite the fact that scientists universally use this label to indicate (relative, absolute) number of cases.

When physicists worked on in-field and out-of-field graphing tasks, they used various resources in their interpretation. In our database, we find considerable differences in the use of linguistic resources between the two fields. This leads to the differences in the extent to which background knowledge is articulated, and in the precision of the knowledge that is rallied in the interpretation. For the out-of-field graphs, physics experts drew more on experience from everyday life or on common sense, whereas in-field graph interpretations more experience from their professional work was used. Many of the out-of-field graph interpretations were limited to literal readings, which participants frequently explained in terms of their lack of background knowledge, and participants confronted breakdown more frequently in out-of-field than in in-field graph interpretations. This result can be thought of as showing that graph interpretation practice reflects familiarity with the world referenced. This finding is consistent with the claim that interpretation does not get information *out of the graph*, but that graphs constitute occasions for the concrete articulation of knowledge of familiar worlds (Roth, 2004). In this sense, success in interpreting graphs is a function of familiarity with the referenced world and of the degree to which the individual establishes a link between representation and world. If individuals are unfamiliar with some graph, they tend to seek connections with their everyday life world and experiences. Graph interpretations then are characterized by common sense and everyday language.

In summary, therefore, practicing scientists’ expertise with respect to reading graphs appears to be more limited than generally thought. More so, the skills that scientists generally exhibit when it comes to familiar graphs—e.g., from their own work or work in their area of research or teaching—is not transferred to introductory-level graphs even if these are from their own domains. Again, the results of this study point to a more limited nature of expertise, which likely is linked to the levels of familiarity with the specific representations and the contextual particulars in which they appear.

ACKNOWLEDGMENTS

The research for this article was funded by a grant from the Social Sciences and Humanities Research Council of Canada. Some of the analyses were developed while working closely with colleagues, including, above all, David Middleton and Jin Yoon. My gratitude goes to them for their interest in my work. G. Michael Bowen (Mount Saint Vincent University, Halifax, Nova Scotia), my peer reviewer, provided incisive comments that allowed me to improve on the penultimate version.

APPENDIX: TRANSCRIPTION CONVENTIONS

In this chapter, I draw on transcription conventions common to conversation analysis enhanced by transcription features specific for researchers interested in marking prosody (Selting et al., 1998). I added specific features for transcriptions that include video offprints. The transcription is neither grammatical—see punctuation—nor consistent with spelling rules but attempts to exhibit the sounds as produced.

Feature in context	Explication
(0.25)	Time in hundreds of seconds
(.)	Pause less than 0.10 seconds
((draws line))	Double brackets surround transcriber comments.
hh, uh	Outbreath, each “h” corresponding to 0.1 seconds.
survi:ve	Colon indicates lengthening of phoneme, each colon corresponding to 0.1 seconds.
r=one	Equal sign means “run-in” of the phonemes or “latching” of different speakers, meaning no pause between phonemes.
084 <<p>point [he:re	Square brackets in consecutive turns indicate extent of overlapping speech, features.
]	
085 [than	
with]	
;.,?	Punctuation marks indicate movement of pitch toward end of utterance segment, down, strongly down, up, and strongly up, respectively
<<p>point>	Triangular brackets mark prosodic features, here “piano,” that is, lower than normal intensity.
Feature in context	Explication
<<pp>point>	“Pianissimo,” much lower than normal speech intensity, next to inaudible intensity.
<<dim>point>	“Diminuendo,” decreasing speech intensity.
<<all>first>	“Allegro,” fast.
<<h>that’s>	Higher than normal pitch register.
[, [2	The bracket marks the coincidence of an offprint (part thereof) with the transcription of words.
↑↓ ‘b ‘clear	Arrows and diacritics indicate movement of pitch: upward and downward jump, downward and upward contour of phonemes that follow.
OR	Capital letters indicate louder than normal speech.

REFERENCES

- Abel, M., Lima Silva, L. A., Campbell, J. A., & De Ros, L. F. (2005). Knowledge acquisition and interpretation problem-solving methods for visual expertise. A study of petroleum-reservoir evaluation. *Journal of Petroleum Science and Engineering*, 47, 51–69.
- Agre, P., & Horswill, I. (1997). Lifeworld analysis. *Journal of Artificial Intelligence Research*, 6, 111–145.
- Bakhtin, M. M. (1986). *Speech genres and other late essays*. Austin: University of Texas Press.
- Bakhtin, M. M./Medvedev, P. N. (1978). *The formal method in literary scholarship: A critical introduction to sociological poetics*. Baltimore: Johns Hopkins University Press.
- Bourdieu, P. (1990). *The logic of practice*. Cambridge, UK: Polity Press.
- Bowen, G. M., Roth, W.-M., & McGinn, M. K. (1999). Interpretations of graphs by university biology students and practicing scientists: towards a social practice view of scientific re-presentation practices. *Journal of Research in Science Teaching*, 36, 1020–1043.
- Edgerton, S. (1985). The renaissance development of the scientific illustration. In J. Shirley & D. Hoeniger (Eds.), *Science and the arts in the renaissance* (pp. 168–197). Washington, DC: Folger Shakespeare Library.
- Garfinkel, H. (1967). *Studies in ethnomethodology*. Englewood Cliffs, NJ: Prentice-Hall.
- Garfinkel, H. (2002). *Ethnomethodology's program: Working out Durkheim's aphorism*. Lanham, NY: Rowman & Littlefield.
- Heath, C., & Luff, P. (2000). *Technology in action*. Cambridge: Cambridge University Press.
- Jefferson, G. (1989). Preliminary notes on a possible metric which provides for a “standard maximum” silence of approximately one second in conversation. In D. Roger & P. Bull (Eds.), *Conversation: An interdisciplinary perspective* (pp. 166–196). Clevedon: Multilingual Matters.
- Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, 4, 39–103.
- Kingsland, S. E. (1995). *Modeling nature: Episodes in the history of population ecology*. Chicago: University of Chicago Press.
- Kozma, R. B., & Russell, J. (1997). Multimedia and understanding: Expert and novice responses to different representations of chemical phenomena. *Journal of Research in Science Teaching*, 34, 949–968.
- Larkin, J. H., & Simon, H. A. (1987). Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, 11, 65–99.
- Latour, B. (1987). *Science in action*. Cambridge, MA: Harvard University Press.
- Latour, B. (1993). *La clef de Berlin et autres leçons d'un amateur de sciences*. Paris: La Découverte.
- Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge, England: Cambridge University Press.
- Linn, M. C., Layman, J., & Nachmias, R. (1987). Cognitive consequences of microcomputer-based laboratories: Graphing skill development. *Contemporary Educational Psychology*, 12, 244–253.
- McNeill, D. (2002). *Gesture and language dialectic*. *Acta Linguistica Hafniensia*, 34, 7–37.

- Ochs, E., Gonzales, P., & Jacoby, S. (1996). "When I come down I'm in the domain state": Grammar and graphic representation in the interpretive activity of physicists. In E. Ochs, E. A. Schegloff, & S. A. Thompson (Eds.), *Interaction and grammar* (pp. 328–369). Cambridge: Cambridge University Press.
- Roth, W.-M. (1996). Where is the context in contextual word problems? Mathematical practices and products in Grade 8 students' answers to story problems. *Cognition and Instruction*, 14, 487–527.
- Roth, W.-M. (2004). What is the meaning of meaning? A case study from graphing. *Journal of Mathematical Behavior*, 23, 75–92.
- Roth, W.-M. (in press). Thinking and speaking: A dynamic approach. In Roth, W.-M. & Tobin, K. (Eds.), *Reuniting psychological and sociological perspectives*. Dordrecht, The Netherlands: Springer-Verlag.
- Roth, W.-M., & Bowen, G. M. (2001). Professionals read graphs: A semiotic analysis. *Journal for Research in Mathematics Education*, 32, 159–194.
- Roth, W.-M., & Bowen, G. M. (2003). When are graphs ten thousand words worth? An expert/expert study. *Cognition and Instruction*, 21, 429–473.
- Roth, W.-M., & McGinn, M. K. (1998). Inscriptions: a social practice approach to "representations." *Review of Educational Research*, 68, 35–59.
- Roth, W.-M., & Middleton, D. (2006). The making of asymmetries of knowing, identity, and accountability in the sequential organization of graph interpretation. *Cultural Studies of Science Education*, 1, 11–81.
- Shafto, P., & Coley, J. D. (2003). Development of categorization and reasoning in the natural world: Novices to experts, naïve similarity to ecological knowledge. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 29, 641–649.
- Suchman, L. A. (1987). *Plans and situated actions: The problem of human-machine communication*. Cambridge: Cambridge University Press.
- Suchman, L. A., & Jordan, B. (1990). Interactional troubles in face-to-face survey interviews. *Journal of the American Statistical Association*, 85, 232–244.
- Vološinov, V. N./Bakhtin, M. M. (1973). *Marxism and the philosophy of language*. Cambridge, MA: Harvard University Press.
- Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.

Chapter 11

CONCEPTUAL COMBINATION: MODELS, THEORIES, AND CONTROVERSIES

Bing Ran¹ and P. Robert Duimering²

¹School of Public Affairs, Pennsylvania State University at Harrisburg
Middletown, PA, US

²Department of Management Sciences, University of Waterloo,
Waterloo, Ontario, Canada

ABSTRACT

This paper provides a comprehensive and critical review of the major theories and models of conceptual combination, by highlighting agreements and controversies in the literature, and identifying future directions for research. The review summarizes the basic arguments of ten major models and then presents an analytical framework to compare and contrast these models along four dimensions: (1) the causal role of schemata in the model; (2) the role of cognitive harmony or consistency in the model; (3) the pragmatic orientation in the model; and (4) the explanatory scope of the model. The review identifies areas of agreement and disagreement among the various models and theories and calls for a synthesis theory to address various theoretical weaknesses and empirical gaps in the current explanations.

1. INTRODUCTION

Conceptual combination refers to the cognitive process by which people use two or more concepts to construct a new conceptual entity that a single concept is insufficient to describe. Researchers agree that the ability to combine concepts plays a fundamental role in diverse cognitive processes such as learning, communication, language comprehension, the composition of thoughts, and the expansion and structuring of knowledge.

¹ Tel: +1 717 948 6057; Fax: +1 717 948 6320 Email: bingran@psu.edu

In the last thirty years, there has been a very strong interest in the cognitive mechanisms involved in combining concepts in cognitive psychology and related fields such as linguistics, artificial intelligence, and philosophy. Many models and theories of conceptual combination have been proposed, among which ten models are of particular significance: Fuzzy Set Theory (Zadeh 1965, 1976, 1982; Osherson and Smith 1981, 1982); the Selective Modification Model (Smith, Osherson 1984; Smith, Osherson, Rips and Keane, 1988); Amalgam Theory (Thagard, 1984); the Concept Specialization Model (Cohen & Murphy, 1984; Murphy, 1988, 1990, 2002); the Composite Prototype Model (Hampton 1987, 1988, 1989, 1990, 1991); the Dual-Process Model (Wisniewski, 1997a, 1997b, 1999; Wisniewski & Love, 1998), the Constraint Model (Costello & Keane, 2000, 2001), the Competition Among Relations in Nominals (CARIN) Model (Gagné, 2000, 2001; Gagné & Shoben, 1997), Coherence Theory (Thagard 1989; 1997), and the Interactive Property Attribution Model (Estes and Glucksberg, 2000; Choi, Oh, Yi & Shin, 2007). This paper will critically review these ten models by identifying areas of agreement and disagreement among them, and various theoretical weaknesses and empirical gaps in the current explanations that might be addressed by a future synthesis theory.

The paper is organized as follows. In the next section each of the ten models will be briefly described and evaluated. Then an analytical framework will be proposed to summarize agreements and controversies among the models. Questionable assumptions and issues in the current theorizing will also be critically examined in the context of a discussion of future directions for conceptual combination research.

2. CURRENT MODELS OF CONCEPTUAL COMBINATION

In this section, we will briefly summarize ten significance models of conceptual combination. The ten models can be sorted into two groups. In the first group, each model was proposed as a logical extension or modification of previous models: Fuzzy Set Theory, Selective Modification Model, Concept Specialization Model, Dual-Process Model, and Interactive Property Attribution Model. Our review will trace the development of these models, focusing on how each addresses earlier theoretical weaknesses. In the second group, the remaining five models each focus on particular aspects of the conceptual combination process: Amalgam Theory, Coherence Theory, Composite Prototype Model, Constraint Model, and CARIN Model. Our review will examine the specific aspects that are emphasized by each model in this group.

2.1. Conceptual Combination as the Intersection of Fuzzy Sets

The earliest attempt to describe the phenomenon of conceptual combination was conducted by mathematicians known as fuzzy set theorists. This attempt generated a formalized explanation of how humans combine smaller conceptual units into more complex ones (Osherson and Smith 1981, 1982; Zadeh 1965, 1976, 1982). The model is based on the idea of referential semantics in which the meaning of a concept represented by a word equates to the extensional set of things denoted by the word. For example, the meaning of the concept

bird refers to the set of all birds. When two concepts are combined, the resulting concept is then the intersection of the two extensional sets. Thus, if X and Y are the extensional sets of concepts x and y respectively, the conceptual combination xy is understood as the intersection of the set X and the set Y , that is the set of things that are both X and Y . For example, the meaning of *pet fish* is the intersection of *pet* and *fish*, i.e., the set of things that are both pet and fish. More formally, in classic set theory, the conceptual combination XY is defined as follows: (Let X, Y be sets) the intersection of X and Y (denoted $X \cap Y$) is the set $\{z : z \in X, z \in Y\}$. In fuzzy set theory, the intersection of two fuzzy sets A and B with respective membership functions $f_A(x)$ and $f_B(x)$ is a fuzzy set C , whose membership function is related to those of A and B by $f_C(x) = \text{Min} [f_A(x), f_B(x)]$, $x \in X$. (Zadeh 1965).

As a formal logic model of conceptual representation, fuzzy set theory provides a strong tool to describe and analyze phenomena such as conceptual combination. The description is clear, logical, and parsimonious. However, as a description of conceptual structure, fuzzy set theory was strongly criticized by psychologists. The major criticisms could be summarized as follows.

The first criticism relates to whether set theory is an appropriate theory of concept representation. For example, the applicability of set theory in concept representation is limited. Osherson and Smith pointed out that the extensional view of concepts “is best suited to ‘kind’ notions (such as *dog*, *tree* and *animal*), to ‘artifact’ notions (like *tool* and *clothing*), and to simple descriptive notions (like *triangular* and *red*) where the extensional sets are easier to define. More difficult to describe are intentional or intricate concepts such as *belief*, *desire*, and *justice*” (Osherson and Smith, 1981 p.38). The diversity of different kinds of concepts imposes difficulties on how set theory formally describes their structure, and whenever non-kind concepts are combined, the intersection of sets is difficult to describe or formalize. Based on this observation, Murphy argued that “(i)t is very difficult to interpret (set theory) as a psychological theory at all. Even if all *pet fish* fall into the intersection of pets and fish, this does not tell us what people do with their concepts *pet* and *fish* in order to create a new concept” (Murphy 1988, p.531). To be considered a psychological model, set theory should provide an intensional explanation of how or why people combine concepts.

The second criticism relates to what are known as conjunction effects. Fuzzy set theory will lead to a contradiction in its calculation whenever an object is more prototypical of a conjunction set than of its constituent sets (Osherson and Smith, 1981). For example, it can be shown empirically that a guppy is more prototypical of the conjunctive concept *pet fish* than it is of either *pet* or *fish*. That is, $C_{\text{pet fish}}(\text{guppy}) > C_{\text{pet}}(\text{guppy})$ or $C_{\text{fish}}(\text{guppy})$. However, the intersection of the fuzzy sets is defined as: $(\forall x \in F) (C_{\text{pet fish}}(\text{guppy})) = \min (C_{\text{pet}}(\text{guppy}), C_{\text{fish}}(\text{guppy}))$ which implies: $C_{\text{pet fish}}(\text{guppy}) < C_{\text{pet}}(\text{guppy})$ or $C_{\text{fish}}(\text{guppy})$. In other words, “it is possible, contrary to fuzzy-set theory, for the characteristicness of an instantiation of a conjunctive concept to be greater than either of the characteristicnesses of its constituent simple concepts” (Jones, 1982 p.284). This apparent contradiction suggests that set intersection is insufficient to describe the conceptual combination process.

The third criticism relates to concepts that are not intersective. For example, Murphy (1988) noted that set intersection does not account for the meaning of combinations like *apartment dog*, which does not correspond to the intersection of the sets *apartments* and *dogs*. Moreover, nonpredicating adjectives, when combined with nouns, do not produce meaningful intersections. “The interpretation of atomic engineer as someone who runs equipment to make

atomic energy is not the intersection of atomic things (whatever they are) and engineers. the intersection of the two sets does not define the combined concept” (Murphy, 2002 p.445).

A final criticism is related to the symmetric property of set intersection which contradicts our intuitive understanding of the meaning of many conceptual combinations. Set theory presumes that noun-noun combinations are symmetric (i.e., true conjunctives), because $X \cap Y$ is equal to $Y \cap X$. However, our intuitive understanding of the combination XY usually has very different meaning than its YX counterpart. For example, “a desk lamp is a kind of lamp, but a lamp desk is a kind of desk” (Murphy, 2002 p.445).

2.2. Selective Modification Model

The weaknesses of using fuzzy set theory to explain conceptual combination led to an alternative explanation: the selective modification model proposed by Smith, Osherson and colleagues (Smith, Osherson 1984; Smith, Osherson, Rips and Keane, 1988). This model consists of two arguments describing how concepts are mentally represented and how these mental representations are combined. The model assumes that concepts are represented by Attribute-value pairs. For example, *apple* may be represented by Color-*red*, Shape-*round*, Taste-*sweet* etc. Each attribute is associated with a certain weight, or “diagnosticity,” which is an empirically-determined numerical value that indicates “how useful the attribute is in discriminating instances of the concept from instances of contrasting concepts” (Smith et al. 1988 p.487). Each value is also associated with a certain weight to indicate its relative salience. For instance, *red* might be more salient than *round* in the *apple* concept, as determined by “votes” for the value by experimental subjects. Despite different terminology, attribute-value pairs essentially correspond to slots (or dimensions) and features in a schematic concept representation (Rumelhart & Ortony, 1977; Rumelhart, 1980).

The model further proposes that the meaning of an adjective-noun combination results from a process of “adjective modification” in which, the adjective modifies the noun: “Each attribute in the adjective concept selects the corresponding attribute in the noun concept; then, for each selected attribute in the noun, there is an increase in the salience (or votes) of the value given in the adjective, as well as an increase in the diagnosticity of the attribute. Consider shrivelled apple as an example. Presumably shrivelled contains attributes pertaining to shape and texture; accordingly, it would select these attributes in the apple prototype, boost their diagnosticities, and shift their votes away from round and smooth and toward irregular and bumpy” (Smith, et al. 1988 p.492).

Selective modification is regarded as the first psychological model of conceptual combination. The main contribution of this model is that it highlighted important aspects of conceptual combination, including typicality effects (i.e., that the typicality of a combination is not a simple function of the typicality of component concepts) and the conjunction effect (i.e., when an item is well described by a conceptual combination, it is usually more typical of that concept than of the two components). However, the model suffers from two major drawbacks. First, the scope of the model is limited to only one kind of conceptual combination, namely predicating adjective-noun phrases such as *red apple* or *long vegetable*. The model does not explain other types of combinations such as nonpredicating adjective-noun combinations like *atomic engineer* (Murphy, 2002) or noun-noun combinations like *telephone television*.

Second, the process of conceptual combination described by this model is problematic. As discussed by Murphy: “The main problem with this theory that later writers have criticized is its assumptions about modification. Consider the way modification works for the concept *red apple*. The adjective *red* finds its match in the schema: There is a feature with the same name. That feature now gets all the votes, and its dimension gets a higher diagnosticity rating. However, there are more complex cases that aren’t so easily accommodated. It has been argued that sometimes, the exact feature would not be present in the concept already, and yet people can figure out how to modify it. Indeed, there may not be an obvious dimension for the modifier to affect. Furthermore, sometimes more than one dimension is altered. Thus, the modification process itself has been argued to be much more complex than Smith et al. let on” (Murphy, 2002 pp.449-450).

2.3. Concept Specialization Model

Murphy and Cohen proposed the concept specialization model to address weaknesses of the selective modification model (Cohen & Murphy, 1984; Murphy, 1988, 1990, 2002). Similar to the previous model, the concept specialization model assumes a schematic representation of concepts where nouns are represented as schemata with slots (dimensions) and fillers (values for each dimension). Based on this representation, “conceptual combination is a process in which a head noun concept (is) specialized by one or more of its slots being filled by the modifying concept” (Murphy, 2002 p.453). In this process, “knowledge is involved in choosing the best-fitting slot” (Murphy, 2002 p.453). For example, to understand the combination *apartment dog*, the modifier *apartment* is used to fill some slot in the head concept *dog*. What dimension or slot of *dog* is picked by the modifier *apartment*? Our background knowledge will guide us to choose the slot of *dog* that makes the most sense with *apartment* as the filler. In this case, *apartment* is classified as a type of Habitat and so fills the Habitat slot in the head concept *dog*. This provides the interpretation of “a dog that lives in an apartment”. Beyond this slot-filling process, the model proposes that further interpretation and elaboration occurs in which we use our background knowledge to expand our initial interpretation. This process seeks to make an interpretation more coherent and complete by retrieving information from our background world knowledge that is relevant to the interpretation. For example, people might elaborate that an apartment dog is cleaner, smaller and quieter than other dogs. This elaboration generates a rich conceptual combination with emergent features that were not part of the original concepts.

As an extension of the selective modification model, concept specialization can account for more complex combinations. As Murphy explained: “one way to relate these two models is to think of the feature weighting model (selective modification model) as a simpler version or subset of the specialization model. That is, the specialization model is very similar in the way it deals with simple features, but it adds another layer of conceptual operations – the elaboration based on world knowledge” (Murphy 1988 p.535). However, later researchers noted two major issues in this model’s explanation.

First, the concept specialization model can account for limited types of interpretations (Costello & Keane, 2000; Wisniewski & Gentner, 1991). The model can only account for conceptual combinations where the head and modifier concepts are linked by some kind of thematic relation, but ignores the possibility of property-based interpretation. Wisniewski &

Markman (1993) used the example *robin hawk* to illustrate. *Robin hawk* could be interpreted as “a hawk that preys on robins”, by filling the Preys slot in the schema representation of *hawk* with the modifier name. The meaning generated this way explains the thematic relation between *hawk* and *robin*. However, it does not allow for properties of the modifier to be transferred into the head representation. This means that an interpretation such as “a hawk with a red breast” cannot be explained by this model.

Second, the process of concept specialization is worth further scrutiny. The model suggests that people attempt to place the modifier into the best fitting slot in the head noun’s schema. However, beyond a metaphorical description, the mechanisms involved in cognitively “filling a slot” are not specified in the model. Intuitively, it is not the whole modifier concept that fills the slot in the head concept. For example, the meaning of *apartment dog* does not result from the whole concept of *apartment* filling the Habitat slot of *dog*, but only certain aspects of *apartment*. The concept of *apartment* has its own rich and complex schematic structure, potentially including dimensions related to rent, size, storey, apartment number, landlord, etc. None of these dimensions would be relevant to the Habitat slot of the concept *dog*, but what happens to them in the slot filling process is not clear.

2.4. Dual-Process Model

Wisniewski (1997a, 1997b, 1998, 1999) proposed the dual-process model as a successor to address some of the weaknesses in the concept specialization model and to account for a wider range of empirical data. The model assumes that concepts are represented by a schematic structure, and proposes three general types of conceptual combination: property-based, relation-based, and hybrid interpretations. “*Relation-linking* interpretations involve a relation between the referents of the modifier and head concepts. For example, people sometimes interpret *robin snake* as ‘a snake that eats robins’. In *property* interpretations, people assert that one or more properties of the modifier concept apply in some way to the head concept, as in ‘snake with a red underbelly’, for *robin snake*. A third, less frequent type of interpretation is *hybridization*. These interpretations refer to a combination of the constituents (e.g., a *robin canary* is ‘a bird that is a cross between the two – half robin and half canary’) or to a conjunction of the constituents (e.g., a *musician painter* could refer to someone who is both a musician and a painter)” (Wisniewski 1997b, pp.168-169). The dual process model proposes that these different interpretations arise from two different cognitive processes: relational combinations result from integration (also known as scenario creation), while property-based combinations result from comparison and construction (hybridization may be considered as both).

In a process similar to Fillmore’s (1968, 1976, 1982) case and frame grammar, scenario creation generates a relation-based interpretation, “...creating a plausible scenario involving the constituents of the combination. ... For example, a plausible interpretation of *truck soap* is ‘soap for cleaning a truck’, because *truck* can be bound to the *recipient* role of *cleaning* (i.e., the thing being cleaned), while *soap* to the *instrument* role (what is used to do the cleaning)” (Wisniewski, 1997b, p.174).

Property-based interpretations start from comparing commonalities and differences between the head and modifier concepts along comparable dimensions, and selecting a property from the modifier to apply to the head. When multiple differences are found, several

factors regulate the choice of the best property to be transferred to the head concept, including the communicative context, the salience of the property, cue and category validity, and plausibility. After comparison, the selected property is used to construct a new version of that property for the combined concept. “The new property must bear enough resemblance to its source in the modifier so that people can determine how the modifier contributes to the meaning of the combination... at the same time, the construction of the new property must not alter the head noun concept in such a way that it destroys its integrity” (Wisniewski 1997b, p.176). For example, “in interpreting *fork spoon*, people could begin by aligning the *handle* of *fork* with the *handle* of *spoon*, and the *end* of *fork* with the *end* of *spoon* and note an important difference: forks have prongs on their ends but spoons have ‘little bowls’ on their ends... the comparison process identifies where in the representation of *spoon* the property ‘has prong’ can be incorporated (on the *end* of *spoon*). However, there is a conflict between mentally connecting this property to the *end* of *spoon* and staying within the referential scope of *spoon*... People can resolve this conflict by mentally attaching the prongs to the end of the little bowl and shortening them or by mentally attaching the prongs to the top of the spoon” (Wisniewski, 1997b, pp.176 - 177).

The dual-process model extends the concept specialization model by providing an explanation of different types of interpretations, by accounting for processes involved in property-based conceptual combinations, and by synthesizing schema based theories of conceptual combination into one model. However, critics of the dual-process model have argued that it lacks a detailed explanation of the underlying cognitive mechanisms involved. For example, Costello and Keane (2006) noted that “the elaboration or construction process ... is clearly a very complex process that is, as yet, unspecified” (p.334). Similarly, Murphy (2002) pointed out that “what is not yet known is the online process by which one of these interpretations is constructed / selected. The feature-mapping process involves comparing the two concepts, identifying a feature of the modifier that could be plausibly transferred over to the head noun, and carrying out that transfer. The slot-filling process involves seeing whether there is a relation available in the head noun that the entire modifier could fill, and then constructing that relation. Furthermore, both of these are complicated by the possibility of construal (e.g., interpreting skunk as referring to a bad smell), which allows many more ways of possibly relating the concepts. How all these alternatives are considered (or if they aren't, how they are ruled out) is at this point not clear” (pp.458 - 459).

2.5. Interactive Property Attribution Model

The interactive property attribution model was proposed by Estes and Glucksberg (2000) as an extension of Wisniewski's dual process model. Specifically, this model provides an explanation of property-based interpretation by suggesting that it is not similarity between component concepts, but feature interactions between the head and modifier, that guide property-based interpretations. By assuming a schematic representation of component concepts, the model proposes that “the modifier and the head play different, but equally important, roles: The head provides relevant dimensions, whereas the modifier provides candidate properties for attribution. For example, in the combination *shark lawyer*, the head concept *lawyer* provides relevant dimensions for attribution (e.g., TEMPERAMENT, COMPETENCE, COST, etc.), and the modifier *shark* provides salient candidate properties

(e.g., “predatory,” “aggressive,” and “vicious”) that can be attributed. ... (I)n the interactive property attribution model ..., instead of exhaustively aligning the dimensions and comparing the features of the two concepts, people align the relevant dimensions of the head with salient properties of the modifier” (Estes and Glucksberg 2000, pp. 29 - 30).

The interactive property attribution model made two important extensions beyond previous models. First, it proposes that the head and modifier do not need to exhaust their complete list of dimensions for comparison and alignment as suggested by dual-process model; instead, only certain dimensions of the head concept are activated which are relevant to salient properties of the modifier. The second extension is the observation that relevance and salience of dimensions and features are context-dependent, rather than context-independent as assumed by most previous models. That is to say, “a salient feature of a modifier may increase or even introduce the relevance of a dimension in the head concept, and vice versa. For instance, NUMBER OF LEGS is not a particularly relevant dimension of *table*, since almost all tables have four legs. However, that dimension becomes relevant in the combination *octopus table*, when interpreted as a table with eight legs” (Estes and Glucksberg 2000, pp. 30).

The preceding five models of conceptual combination have been reviewed chronologically according to their first appearance in the literature, because each can be regarded as an extension or replacement of previous models, which addresses prior limitations and offers increasing explanatory power. The remaining five models to be reviewed were proposed over a similar time-frame, and emphasized particular aspects of the conceptual combination process, but were not proposed as explicit extensions of previous models.

2.6. Amalgam Theory

Thagard (1984) proposed a theory of conceptual combination within the context of philosophical investigations on the phenomenon of scientific concept development. It is “a theory of how new concepts can arise, not by abstraction from experience or by definition, but by conceptual combination. Such combination produces a new concept as a non-linear, non-definitional amalgam of existing concepts” (Thagard, 1984 p.3). The basic claim of amalgam theory is that “conceptual combination requires mechanisms for reconciling the conflicting expectations contained in the candidate concepts” (Thagard, 1984 p.4).

Using formalized language, this theory assumes a schematic representation of concepts (the paper adopted the term “frame” from Minsky 1975) with slots and values (i.e., each concept has slots C_i with values $C_{i,1} \dots C_{i,n}$), and proposes that a new concept C_3 is formed from initial concepts C_1 and C_2 by selecting from $C_{1,j}$ and $C_{2,k}$, a subset of slots $C_{3,m}$ for combined concept C_3 . Thagard proposed six procedural rules to regulate the process of slots and value selection. For example, “a concept concerning a kind of physical object which has a value for size is also likely to have a value for weight. Conceptual combination should preserve such linkages” (p.7). Other rules propose that if a slot is chosen by conceptual combination, the value of the slot will depend on the adjectival concept, the variability of the concept, specific examples of the combination, or the representativeness of given instances of the combination. Specifically, the theory proposed that when we try to reconcile conflicting slots, we tend to favor those that contribute to desired problem solutions. For example,

“suppose that in forming the combined concept of a Canadian violinist you notice that your friend the Canadian violinist prefers hamburgers to classical French cuisine. In order to explain this preference, you may add the default expectation about Canadians to your frame for Canadian violinist, overruling the expectation derived from the frame for violinists” (Thagard, 1984 p.9). To reconcile the conflicting preference of food by *Canadian violinist*, we favor the connotation that “Canadians usually prefer hamburgers” to resolve the conflict that was brought in by *Canadian* and *violinist* (who supposedly prefer classical French cuisine).

Amalgam theory was the first model to suggest that conceptual combination is a kind of problem solving process of reconciling conflicting expectations contained in the candidate concepts. This general line of thinking is consistent with Thagard’s (1997) later theorizing of coherence on this problem (to be discussed below). The six procedural rules specify how features of the candidate concepts and empirically observed instances are reconciled into a non-conflicting set for the new, combined concept. However, how these rules might be implemented cognitively is not specified by the theory. Further, the theory emphasizes the importance of specific examples in resolving the conflicting expectations contained in our component concept schema. For example, four of the six rules are example-driven procedures, in which empirical observations influence the meaning of a combination. However, some conceptual combinations do not have ready-made examples, especially novel combinations such as triangular basketball or tasty computer. How conflicting expectations are reconciled for such novel combinations needs more theoretical exploration.

2.7. Composite Prototype Model

Hampton proposed the composite prototype model (Hampton 1987, 1988, 1989, 1990, 1991) at about the same time as Murphy proposed the concept specialization model. The model assumes that concepts are represented schematically as sets of attributes connected by theory-driven relations. For example, we might know that birds have wings and can fly (attributes) and that having wings is an enabling condition for flight. Attributes are assumed to have a quantitative “degree of definingness” called Importance². “At the top end of the scale of attribute importance there may be some attributes which are so important as to be necessary for category membership. For example HAS GILLS may be treated as a necessary attribute of FISH” (Hampton 1991 p.106).

Based on these assumptions, Hampton proposed that “a conjunctive concept is then represented semantically by a composite prototype... which is formed as the union of the sets of attributes from both ‘parent’ (constituent) concepts. Thus initially the concept PET FISH will have all the attributes of both PET and FISH prototypes” (p.107). The combined set of attributes is then modified based on a necessity constraint, which specifies that a necessary attribute of one constituent concept will also be a necessary attribute for the conjunctive. For example, if has gills is necessary for fish, then it will also be necessary for pet fish. For non-necessary attributes, their importance is determined as a monotonic positive function of

² The notion of importance has been proposed as definingness (Smith, Shoben, and Rips, 1974), cue validity (Murphy, 1982), diagnosticity (Smith & Osherson 1984) or centrality (Barsalou & Billman, 1989). It reflects the relative likelihood of an item belonging to a category given that it does or does not have the particular attribute.

importance for each constituent concept and attributes with low average importance will be dropped from the conjunctive set.

After forming the set of attributes for a conceptual combination, a consistency checking procedure is applied, and “(w)here there are incompatible attributes, a choice has to be made to delete certain attributes” (p.107). The consistency constraint incorporates several rules. When a non-necessary attribute of a constituent concept has a conflict with the necessary attribute of the other constituent concept, it will not be used by the conjunctive. “For example, if PETS typically breathe air, but this is inconsistent with living underwater, which itself is necessary for the concept FISH, then breathing air will not be possible for PET FISH” (p.108). When the conflict is between two necessary attributes of two constituents, then the conjunction is an empty set - a “logical impossibility” (p.108). “When the conflict involves two non-necessary attributes, then the choice of which to delete will depend on their relative importance, on the overall consistency that can be achieved with respect to the other inherited attributes, and on the context in which the phrase is being used” (p.108).

The composite prototype model contributes by proposing the necessity and consistency constraints, which exhibit a strong pragmatic orientation. This model is applicable to both novel and mundane combinations. As Hampton (1991) explained, “the proposed model could be applied to the conjunction of well-defined concepts with a core of common element defining features, with the desired results. The necessity constraint would ensure that all defining features of each concept remain critical for the conjunctive concept, and the consistency constraint would ensure the correct identification of nonoverlapping sets. Well-defined concepts would therefore require no different treatment in the model” (p.108).

It is notable that this model bears some similarity to fuzzy set theory, in that the union of the attribute sets of constituent concepts corresponds closely with the intersection of the extensional sets denoted by each constituent concept. Hampton’s model can, therefore, be viewed as a kind of extension of fuzzy set theory by suggesting cognitive processes involved in the intersection of extensional sets. It also bears similarity to Wisniewski’s hybridization interpretation whereby the meaning of a conceptual combination is taken to be a hybrid of the constituent concepts.

2.8. Constraint Model

The constraint model was proposed by artificial intelligence scholars Costello and Keane (1997a, 1997b, 1998, 2000, 2001). This model focuses on the efficiency of the conceptual combination process based on pragmatic principles, which have been implemented as a computational model called C3. The following will focus on the theoretical model and ignore technical details associated with its computational implementation.

Similar to other models, the constraint model assumes that concepts are represented in a schematic structure. When people understand a novel combination, they construct a combined concept to represent that combination. In the process of combining, people assume that everyone involved in the communication follows the cooperative principle as theorized by Grice (1975). “Three constraints ... follow from this assumption. By following these constraints the listener can construct the correct concept as intended by the speaker” (Costello 2004). The first constraint is called plausibility. Because it is assumed that everyone in the communication is cooperating, the intended combined concept should be something the

listener already somewhat knows. Thus the listener assumes that the new combined concept must describe something plausible which is similar to things the listener has seen before. The second constraint is called diagnosticity. Because the speaker is assumed to be cooperating, the intended combined concept is one best identified by the two words in the phrase (otherwise the speaker would have selected other words). Thus the listener knows that the new combined concept must contain some properties which are best identified by (that is, are diagnostic of) each word in the phrase. The third constraint is called informativeness. Because the speaker is cooperating, the intended combination is one for which both words in the phrase are necessary (otherwise the speaker would have used fewer words). Thus the new combined concept must be more informative than either of the constituent words. Costello illustrated his idea with the example of *shovel bird* understood as “a bird that has a flat, wide beak like a shovel, for digging worms” (2004). In this case, the listener constructs an understanding with the diagnostic properties of *shovel* (flat, wide, and used for digging) that is something plausible (bird digging worms) and informative (flat, wide beak).

The constraint model contributes by emphasizing pragmatic principles and addressing the possibility of multiple interpretations for novel combinations and how different interpretations are selected. For this reason Costello (2004) describes the model as a pragmatics of conceptual combination. Theoretically, however, it is notable that Grice discussed cooperation in communication in relation to four cooperative principles (quality, quantity, relevance, and manner), to explain how listeners could arrive at a speaker’s meaning and why speakers could mean more than they said. Grice argued that it is a violation of the cooperative principles that produces extra meaning not contained in what is said. Although the constraint model borrows the general idea of cooperation, the proposed plausibility, diagnosticity, and informativeness constraints do not correspond directly to Grice’s four cooperative principles. Thus, whereas many communicative and pragmatic constraints may influence human cognition, why these particular three are emphasized by Costello & Keane is not clear.

2.9. Coherence Theory

Thagard (1997) proposed a coherence theory of conceptual combination following the basic line of thinking in his 1984 paper that conceptual combination involves solving a problem by reconciling conflicting expectations contained in the candidate concepts. The basic argument of coherence theory is that elements in a conceptual system (concepts, propositions, parts of images, goals, actions etc.) can cohere (i.e., fit together) or incohere (i.e., resist fitting together; Thagard, 1989, 1997, 1998). If two elements cohere, there is a positive constraint between them. Otherwise, there is a negative constraint between them. “A positive constraint between two elements can be satisfied either by accepting both of the elements or by rejecting both of the elements. A negative constraint between two elements can be satisfied only by accepting one element and rejecting the other. The coherence problem consists of dividing a set of elements into accepted and rejected sets in a way that satisfies the most constraints” (Thagard & Verbeurgt 1998 pp.2-3). Conceptual combination is therefore viewed as an “instance of coherence conceived of as maximization of constraint satisfaction” which “requires us to apply some concepts to a situation and withhold other concepts in such a way as to maximize the overall satisfaction of the constraints determined

by the positive and negative associations between the concepts” (Thagard 1997). In practice, Thagard models such problems by constructing a constraint network with elements of all possible inferences of the head and modifier concepts. He then uses certain connectionist algorithms to propagate association weights in a way that maximizes coherence by accepting some elements and rejecting others. The output is “an interpretation of the relation between the head and modifier, as well as a collection of inferences about the object denoted by the head as characterized by the modifier. If the most coherent interpretation is nevertheless not very coherent, then move to other mechanisms such as analogy and explanation that produce incoherence-driven conceptual combinations” (Thagard 1997).

Thagard (1997) used racial stereotypes associated with the conceptual combination *well-dressed black* to illustrate. He suggested that people confronted with this combination might activate a network of associated concepts such as *aggressive* or *poor ghetto inhabitant* for *black*; and *businessman*, *not poor* and *not aggressive* for *well-dressed*. The positive constraints in this network include the associations that ghetto blacks are aggressive, while negative constraints include the negative association that ghetto blacks tend not to be businessmen. Apparently, this is not a coherent network. To understand the meaning of this combination, we need to come up with the most coherent interpretation, which best satisfies the constraints. A connectionist algorithm is used to maximize coherence by rejecting *aggressiveness*, resulting in the interpretation of *well-dressed black* as “a black businessman who is not an aggressive ghetto black”.

Different from his earlier amalgam theory, Thagard’s coherence theory does not depend on schematic concept representation and uses connectionist logic to achieve coherence rather than a system of logical rules. Perhaps the most important contribution of this theory to the field of conceptual combination is the explicit orientation toward coherence and consistency in a cognitive network. The basic assumption is that a conceptual network tends to evolve toward a more stable and harmonious state through “the maximal satisfaction of multiple positive and negative constraints that is achieved by some parallel constraint satisfaction algorithms” (Thagard & Verbeurgt 1998 p.1). As such, coherence theory exhibits a basic assumption of goodness-of-fit or harmony as emphasized by Gestalt psychology. However, as explained by Thagard (1997), the current coherence-driven constraint-satisfying model has difficulties explaining non-predicting combinations such as *apartment dog* and incoherence-driven novel combinations like *web potato* where meaning may be motivated not by coherence but by the failure to find coherence. Finally, the connectionist algorithms used in coherence theory are not a direct reflection of mental activity, but a simulated approximation of the mind.

2.10. CARIN Model

The Competition Among Relations In Nominals (CARIN) theory (Gagné, 2000, 2001; Gagné & Shoben, 1997, 2002) provides a model of conceptual combination that uses our prior experience of the kinds of thematic relations that words have in compounds to predict what interpretations people will produce, and what compounds people will find easiest to understand. In linguistics, thematic relations between two words in a compound have often been examined by developing taxonomies of relations required for interpreting combinations (Kay & Zimmer, 1976; Gleitman & Gleitman, 1970; Downing 1977; Levi, 1978). For

example, Levi (1978) identified 15 thematic relations (such as Cause, Has, Make, For, Is, Use, About, etc.) to classify the meanings of many familiar compounds.

Unlike models which use a feature based schematic representation of concepts, the CARIN model assumes a kind of schematic representation of the relations between concepts. That is to say, it assumes a slot-type structure where slots are not features of the concept but of the kinds of thematic relations it can have with other concepts. The internal feature representation of concepts is largely irrelevant in this model, where the goal of conceptual combination is to fit compounds into existing relational templates. Specifically, the model argues that people possess distributional knowledge based on their experience of how often particular relations are used with particular concepts, corresponding with variable relation strengths for concepts. These relations “compete for the interpretation of the combined concept and ... the difficulty of interpretation is a function of the relative strength of the selected relation. ... Interpretations are easier if the required relation is of high strength than if the thematic relation is of low strength. Other things being equal, it is easier to arrive at the correct interpretation for *mountain stream* than it is for *mountain magazine* because the Locative relation has a greater strength relation than does the About relation” (Gagné & Shoben, 1997 p.81). Thus combinations involving typical thematic relations will be easier to understand than those involving atypical relations.

The CARIN model proposes a linguistic taxonomy of 16 thematic relations between component words, including Cause, Has, Make, For, Is, Use, Located, etc. By paying attention to the kinds of thematic relations that words assume and adding weights to these relations, the model predicts the priority between different thematic relations when constructing an interpretation for a compound. The model differentiates between the roles of the head and modifier concepts and, unlike other models which primarily emphasize the head concept, CARIN places most emphasis on the modifier by suggesting that it selects a thematic relation for the compound during the combination process. It is easy to conclude, however, that the 16 relations proposed in the model are too abstract to capture the variety of meaningful interpretations that can arise in conceptual combinations. For example, the combinations *birthday cake* and *bravery medal* share the For relation between their components. However, treating these as the same relation overlooks crucial differences between the interpretations of For in these two combinations: a birthday cake is a cake *used for the purpose of* celebrating birthday while a bravery medal is a medal rewarded *because of* bravery. The relations denoted by simple words such as Make or For imply very complex meanings corresponding to complex conceptual structures. Using this complex conceptual structure to link two concepts will inevitably result in a rather vague interpretation. In general, each of the 16 proposed relations is itself a category of diverse relational meanings, which lacks the precision to account for particular interpretations of conceptual combinations.

3. AGREEMENTS AND CONTROVERSIES – AN ANALYTICAL FRAMEWORK

The preceding review demonstrates that conceptual combination research has produced a variety of theories with different emphases and terminology. As such it is impossible to compare and contrast every aspect of the literature in this paper. However, we will use a

relatively coherent analytical framework to summarize the major issues related to conceptual combination and to provide a basis on which to compare and contrast the models and theories in an integrative way. The framework consists of four dimensions reflecting major characteristics of the various models: (1) the causal role of schemata in the model; (2) the role of cognitive harmony or consistency in the model; (3) the pragmatic orientation of the model; and (4) the explanatory scope of the model. In addition to using the framework to summarize major characteristics of the models, we will also provide a critical analysis and challenge some of the fundamental assumptions related to these four dimensions. Table 1 summarizes major characteristics of the ten models in relation to our framework.

3.1. The Causal Role of Schemata

Perhaps the most prominent aspect of the conceptual combination literature is that most models rely on schema theory in two ways. First, most models assume a schematic representation of conceptual structure. Except for fuzzy set theory and coherence theory, all of the current models assume a schematic representation of noun concepts as dimension-value pairs. Although the CARIN model emphasizes thematic relations between the two constituent concepts, if thematic relations are understood as a kind of dimension reflecting how concepts connect with one another, then there is not too much difference between feature-based schema models and thematic relation models. Second, schemata play a causal role in the cognitive mechanisms proposed by many of the models, where conceptual combination is understood in terms of certain cognitive operations that take place along dimensions in the schema. For example, the selective modification, concept specialization, dual process, CARIN, and interactive property attribution models all propose cognitive processes related to the idea of slot-filling, where a modifier, or some aspect of a modifier, fills a slot in the head concept schema. Schemata play a different causal role in the composite prototype model, which proposed mechanisms of composing a schema to represent the conceptual combination from the union of the prototypical attributes of both component concepts, based on necessity, importance, and consistency constraints. Only the constraint model appears to assume a schematic concept representation, which plays no obvious causal role in the operation of its three proposed constraint mechanisms (plausibility, diagnosticity, and informativeness).

Despite their fundamental roles in current theories of conceptual combination, several questions could be raised about the nature of schemata and the workings of associated cognitive processes such as slot filling. The causal role of schemata in current theories of conceptual combination is based on several problematic assumptions: 1. Schema represents our fundamental conceptual structure, independent of communicative context; 2. Pre-existing schema dimensions and values are necessary, sufficient, and exhaustive for cognitive processing; 3. The weights associated with a schema's dimensions and values are absolute and will carry over to any cognitive processing task. There are issues related to each of these assumptions.

The first assumption, that schema represents our fundamental conceptual structure, deals with the nature of schema as either intrinsic to our cognition or retrospectively imposed. Schema theory describes "how knowledge is represented and about how that representation facilitates the use of the knowledge in particular ways" (Rumelhart 1980 p. 34). Schema theory assumes a logical structure to organize knowledge in the human mind, in which

features are organized at a lower conceptual level relative to the super-ordinate dimensions. This structure seems to match our intuitive experience: when we think about a concept, we may feel that it is logically related to other concepts in a manner similar to the dimensions or values proposed by schema theory. For example, we may know that apples are typically red and that red is a color, so the concepts *apple*, *red*, and *color* have a logical relationship that could be described by an *apple* schema consisting of a dimension/slot *color* with value *red*. However, the fact that we understand these concepts as being logically related to one another does not necessarily imply that our minds represent them in such an organized manner in permanent memory. It is possible that our minds represent knowledge in less structured ways and that logical structure is imposed after the fact, as part of online processes of thinking about these concepts and the logical relations between them. Hierarchical concept taxonomies serve situation-specific purposes or goals, suggesting that they may be created or activated online in response to communicative context, rather than permanently stored in memory. *Red* might be a subordinate concept within an *apple* schema if we are selecting fruit at the supermarket, but *apples* might be subordinate to *red* if we are classifying objects based on color, and *red* might be irrelevant to *apple* if we are thinking metaphorically about New York City.

The second assumption that a schema's pre-existing set of dimensions and values are necessary, sufficient, and exhaustive for cognitive processing is quite problematic. The fact that we can quite easily make sense of novel combinations counters such a view. For example, the novel combination *smart apple* has the same structure as the more mundane *red apple*, but it is hard to imagine that our schematic knowledge of *apple* would include an intrinsic dimension/slot for *intelligence* with different values in *smartness*. How many dimensions are needed to account for all of the possible knowledge that we have regarding a concept and for all potential conceptual combinations? How would we know whether a limited number of dimensions such as *color*, *shape*, *texture*, etc. would be capable of representing our complete knowledge of the concept *apple*? What about social concepts such as *country* and *suicide*, or abstract concepts like *love* and *hate*? How should we determine a necessary, sufficient, and exhaustive set of slots/dimensions for these kinds of concepts? Apparently, certain extra dimensions or associations must be activated and constructed online in the process of conceptual combination, rather than being stored in memory independent of context.

By the same token, many schema dimensions may be eliminated or filtered out in the process of conceptual combination. It was observed earlier that the specific cognitive mechanisms involved in filling a slot are not specified by any of the current models of conceptual combination. The example of *apartment dog* was used to illustrate that the modifier concept *apartment* is at least as complex in structure as the head concept *dog*, including potential dimensions related to rent, size, storey, apartment number, landlord, etc., yet most of these are irrelevant to the meaning of this combination. Thus, if *apartment* fills a *habitat* slot in *dog*, is it the entire complex modifier concept that fills the slot? Or is much of this conceptual structure filtered out during the combination process, and if so, how does this filtering process work? In general, most current models place primary emphasis on the structure of the head noun schema and overlook both the potential complexity of the modifier schema structure and theoretical difficulties associated with the slot filling process.

The third assumption, that the weights associated with dimensions and values in a schema are absolute and will carry over to any cognitive processing task, deals with the way that the

importance, saliency and diagnosticity of an attribute are evaluated in various models of conceptual combination. In some of the models, the importance and diagnosticity of an attribute are evaluated within the concept itself and treated as an absolute value. Thus, if certain attributes are most central for category membership, they will be assigned a higher weight which will be carried over to the combination. However, when combining concepts, the importance of an attribute is not just related to individual concepts alone. The weight of an attribute seems to vary in relation to the context in which the concept is used. In other words, diagnostic and important features of a concept depend on the set of other concepts that are salient at the time of use and should not be evaluated just within a single concept. For example, when the meaning of the novel combination *chocolate computer* is understood as “a chocolate shaped like a computer”, most of the attributes of *computer* are dropped regardless of how important they might be for the individual concept, and the importance of the dimension *shape* increases from a low weight to the much higher value for this combination.

Based on this analysis of assumptions underlying schema-based models, we would argue that a schematic representation of conceptual structure is insufficient to account for the complexity of conceptual combination. Pre-existing schema dimensions and values cannot provide a necessary, sufficient, and exhaustive set of knowledge resources appropriate to the required cognitive processing. A different model of how conceptual information is stored and processed in the mind is needed to address the preceding limitations. In this respect, Thagard’s coherence theory may suggest a potential alternative in that its proposed cognitive mechanisms do not depend on a priori schematic conceptual structure. Instead of an overly restrictive schematic representation, a connectionist framework requires only that networks of associated concepts are activated online during cognitive processing.

3.2. The Role of Cognitive Harmony or Consistency

The second dimension of our analytical framework considers the role of cognitive harmony or consistency in conceptual combination. When we combine two previously unrelated concepts, there might be conflicting connotations, expectations, and attributes contained in the component concepts that need to be reconciled before a coherent understanding can be generated. For example, in the combination *television cellphone*, the first concept *television* might bring in the attributes of *large screen* and *a remote control*, which would conflict with attributes of the second concept *cellphone* such as *small screen* and *no remote control* respectively. Three conceptual combination models (amalgam theory, coherence theory, and composite prototype model) propose explicit consistency checking mechanisms for combining concepts with conflicting expectations to generate a meaning that is coherent, consistent and harmonious. Amalgam theory proposes six procedural mechanisms by which features from candidate concepts and instances are reconciled into a non-conflicting set for the new, combined concept. The composite prototype model proposes mechanisms that focus on how necessary attributes of head and modifier influence the meaning of the combined concept. Coherence theory proposes parallel weight propagation among elements in a conceptual network to maximize coherence. Two other models (the concept specialization and dual-process models) discuss the issue of consistency implicitly by suggesting that world knowledge is used to construe or clean up conflicts in the combined concepts.

Consistency is discussed intuitively without an explicit operationalization in most of these models, but Hampton proposed a means of empirically estimating attribute coherence scores as part of the composite prototype model. For example, “the PET and BIRD attributes were set up as rows and columns of a two-way matrix, and ... subjects ... were instructed to take each row attribute in turn and to rate it against each column attribute using a scale from +2 meaning can occur together, to -2 meaning impossible to occur together ... For each attribute, an average coherence score was calculated, based on the mean ratings given to the attribute, averaged across subjects and across the attributes of the other concept” (Hampton, 1987, pp. 66). This is a useful contribution in that it provides a way to measure the degree of consistency empirically, rather than relying on an intuitive notion of consistency, and in the case of coherence theory could be used to validate connectionist simulation models.

Consistency and harmony issues are usually approached from the connectionism and consistency perspectives in cognitive psychology. Connectionism began in the field of artificial intelligence with the goal of understanding cognition by viewing the brain as a network of interconnected neurons (Rumelhart et al. 1986). Connectionist models consist of interconnected and distributed processing units that perform simple computations concurrently transforming inputs into outputs to neighboring units. Thagard’s coherence theory follows this connectionist tradition in terms of the basic assumptions of goodness-of-fit or harmony. The idea of harmony in connectionist approaches is also very similar to what has been historically called cognitive balance or consistency in the psychological literature. Consistency theories began in 1940s and include a group of theories that were proposed in attempts to “uncover the structural-dynamic characteristics of human cognition” (Simon & Holyoak 2002, p.283) towards consistency. “These conceptions, symmetry, consonance, balance, and simplicity, are, of course, implied in that idea with which Gestalt theory started and which always was central to it, namely, the idea of a ‘good’ figure... this model implies a number of different entities with certain properties and standing in certain relations, which make up a constellation of factors tending toward a standard (consistent) state” (Heider, 1960 p.168).

The basic assumption of these theories is that inter-related cognitive elements tend to form a stable structure, whereas inconsistent elements are associated with psychological tension and a tendency towards reestablishing stability or harmony. Conceptual combination could be understood as forming a stable structure of attributes associated with two component concepts, such that conflicting attributes associated with each concept are reconciled. Particularly in the case of novel combinations, perceived inconsistency among attributes may be associated with tension and psychological forces to reorganize the cognitive elements into a more balanced or harmonious state. For example, we might interpret *elephant fish* as “a fish with a trunk,” but nonetheless experience some residual psychological imbalance or discomfort in relation to this constructed meaning. The remaining imbalance comes from perceived inconsistency between this constructed interpretation and a larger cognitive field associated with our background knowledge of concepts associated with *elephant* and *fish*. In this circumstance, it is likely that further cognitive effort beyond the initial interpretation will be exerted to make the larger field harmonious. What cognitive mechanisms are involved in reducing discomfort and making the system of attributes coherent and harmonious? How do we empirically examine the state of harmony before and after a combination? How could the tradition from consistency theories and connectionist models be carried over to the research

of conceptual combinations so that we do not re-invent wheel when proposing explanations? Future models of conceptual combination should address these sorts of questions.

3.3. The Pragmatic Orientation

The third dimension in our framework considers the pragmatic orientation of conceptual combination models. Studying how people construct and understand a conceptual combination is largely the study of how meaning is constructed and communicated in the context of a two-word combination. There are two senses of meaning in this situation: the semantic meaning and the pragmatic meaning. Semantic meaning refers to the literal meaning or the informative intent of an expression, whereas pragmatic meaning refers to the implied meaning or the communicative intent of the expression. A nice way to think about the difference is that semantics considers “what X means”, while pragmatics considers “what a speaker means by saying X”. Five of the models reviewed (amalgam theory, concept specialization model, dual process model, constraints theory, and interactive property attribution model) consider pragmatic aspects of the communicative context in their explanation of conceptual combination, where communicators might cooperate to achieve intended meaning, use context and general knowledge to contribute to the meaning of the combination, or make sense of the combination in terms of judging the plausibility, intention, goal, and appropriateness of the combined concepts. However, the degree of emphasis and the focus on pragmatic principles varies greatly between the five models.

For example, amalgam theory proposed that there are three kinds of conceptual combinations, pure, data-driven, and goal-directed, based on the degree that context is involved. A context could consist of prospective instances of the new combined concepts, or of a goal of solving a problem by reconciling the conflicting expectations contained in the candidate concepts. The interactive property attribution model discusses only the linguistic context of the combination, involving the collocation and pairing of words in the combination, rather than a broader communicative context that might contribute to the construction of a plausible and appropriate meaning. The concept specialization model does not consider how context or communicative intent contribute to meaning, but relies heavily on the concept of “background knowledge” to explain the plausibility and appropriateness of the meaning of combinations. As a direct descendent of the concept specialization model, the dual-process model has a stronger pragmatic orientation and discusses how context, plausibility, informativeness, and definingness contribute to comparison processes and the construction of combined meaning. Costello and Keane’s (2000) constraint model explicitly proposed three pragmatic constraints that influence conceptual combination – diagnosticity, plausibility and informativeness – and implemented them in a computational simulation. However, the underlying cognitive mechanisms that might correspond to these constraints are very vague. In computer simulations, for example, Costello and Keane operationalized the informativeness constraint as the appearance of a new predicate that was not contained in the prototype of the head concept but whether similar processes might operate in the mind is unknown.

Constructing the meaning of a conceptual combination involves numerous factors, among which the communicative context is undoubtedly one of the most important. Conceptual combination is largely a problem of communication, where someone intends to communicate

a meaningful message to others with a certain context. Pragmatics provides useful tools to help conceptualize this process. However, current models that include pragmatic considerations generally lack detailed explanations of how pragmatic factors function cognitively. For example, Murphy proposed that knowledge serves two functions in the concept specialization model. “First, outside knowledge must often be consulted in order to decide which slot is the appropriate one to specialize... the second reason for consulting outside knowledge is to elaborate or clean up the concept in order to make it more coherent and complete” (Murphy 1988 p.533). However, the nature of “outside knowledge” is not clearly defined and is treated as a kind of black box in which the cognitive mechanisms that guide its function are unknown. Similar observations could be made about variables such as context, appropriateness, and relevance in various models. These pragmatic factors have face validity, but the cognitive mechanisms underlying them are in need of more detailed specification.

One reason such cognitive mechanisms may be difficult to specify is an apparent assumption that pragmatic constructs such as context or knowledge require a different representation and treatment than that used for conceptual meaning. Is it possible that we could treat meaning, context, and knowledge in more or less the same way, using a common representational scheme, so that whenever we discuss the meaning of a conceptual combination, we naturally include aspects of context and knowledge in the discussion? Ideally, future models of conceptual combination need to consider how pragmatic factors could be integrated with conceptual meaning in a parsimonious fashion.

3.4. Explanatory Scope

The last dimension of our framework compares the theories of conceptual combination based on the explanatory scope of each model, referring specifically to the following four distinctions: novel vs. mundane combinations, true vs. spurious conjunctives, head vs. modifier roles, and noun-noun vs. adjective-noun combinations. With respect to the first of these distinctions, a mundane combination is the one that is commonly used in everyday language, such as *red apple*, while a novel combination is the one that rarely if ever appears in our daily language, such as *elephant fish*. It has been suggested that novel conceptual combinations are a key source of creative thought, thus several of the models focus on the cognitive processes of combining concepts in novel ways.

For the second distinction, a true conjunctive refers to a symmetric conceptual combination of two component concepts (X and Y), such that the combined concept (XY or YX) represents something that is a member of both category X and Y, regardless of component sequence. On the other hand, if XY and YX have different meanings, they are considered to be spurious conjunctives. For example, if *pet fish* has the same meaning as *fish pet* it is a true conjunctive. Two models of conceptual combination explicitly focus on true conjunctives. In fuzzy set theory the meaning of a combination is defined symmetrically as set intersection (i.e., $X \cap Y = Y \cap X$). In the composite prototype model a particular syntactic structure of “X that is also Y” is used in experiments to ensure that combinations reflected true conjunctives (e.g., “machines that are also vehicles,” “furniture that is also a household appliance,” etc.). Most of the other theories, however, assume that XY and YX have different meanings and, therefore, focus their attention on spurious combinations.

The third distinction relates to the different roles of head and modifier concepts in contributing to the meaning of a combination. In the current literature, the head noun or head concept (sometimes simply called head) refers to the central word or concept in the combination (usually corresponding to the second word in the combination in the English language). The modifier refers to the word or concept in the combination that changes some aspect of the head (usually corresponding to the first word in the combination in English). Five of the models explicitly discuss the role of head or modifier, but they differ with respect to which concept is believed to contribute most to the combined meaning. The selective modification, concept specialization, and dual process models propose that the head concept dominates the meaning of the combination, while the CARIN model proposes that the modifier dominates by selecting thematic relations for the combination. The interactive property attribution model proposes that both head and modifier contribute equally to the meaning of the combination.

The fourth distinction is between noun-noun and adjective-noun combinations. It is interesting to note that grammatical terminology is often intermingled with cognitive terminology in the current literature. When we define conceptual combination as a combination of two (or more) concepts, we are discussing the cognitive structure of this combination. However, cognitive structure cannot be explicitly discussed without reference to the grammatical structure of words and their relations. Thus in all of the current models, a combination of two concepts equates to a combination of two words. For example, the two-word combination “elephant fish” refers to a combination of two concepts *elephant* and *fish*. Because of this, researchers frequently use grammatical terms to refer to cognitive combinations. Noun-noun combinations, such as “zebra bird,” refer to combinations of two concepts represented by nouns in the English language. Adjective-noun combinations, such as “red apple,” refer to combinations of one noun concept and one adjective concept that, arguably, refers to a feature of the object denoted by the noun. The latter are sometimes sub-categorized into predicating adjective-noun combinations (e.g., “beautiful story”) in which the combination can be re-written into a semantically correct sentence (“story is beautiful”), and non-predicating adjective-noun combinations (e.g., “atomic engineer”) in which the combination cannot be re-written into a semantically correct sentence (i.e., the sentence “engineer is atomic” is meaningless). Except for the selective modification model, most of the current models are intended to explain noun-noun combinations and only a few are adequate to explain adjective-noun combinations.

These four distinctions (novel vs. mundane combinations, true vs. spurious conjunctives, head vs. modifier, and noun-noun vs. adjective-noun) are based on current terminology used in the literature to characterize the explanatory scope of the ten models. However, it should be noted that these distinctions themselves raise certain questions of concern in relation to theorizing about the conceptual combination process.

First, the assumption of the existence of genuinely conjunctive concepts is questionable. Zadeh (1982) assumes that conjunctive concepts are distinguishable from spurious conjunctions and that fuzzy set intersection is applicable only to genuinely conjunctive concepts. Psychologically, if we artificially define concepts strictly in terms of categorical denotations, there may be genuine conjunctives representing something that is both in category X and Y. Hampton (1988) used such a strategy in experiments by directly asking subjects to think about conjunctives like “machines that are also vehicles.”

Table 1. A summary of the ten models evaluated against the analytical framework

	Schema		Consistency	Pragmatic orientation	Explanatory scope				
	schematic representation	schema as causal factor	reconciling conflicting expectation	context, intent, plausibility, goal, appropriateness	head - modifier	noun-noun	adjective-noun	mundane vs. novel	true vs. spurious conjunctives
Interactive property attribution	yes	yes	no	somewhat	yes	yes	no	novel	spurious
CARIN	yes	yes	no	no	yes	yes		both	spurious
Coherence	no	no	yes	no	no	yes	yes	both	not explicit
Constraint	yes	no	no	yes	no	yes	no	novel	spurious
Dual process	yes	yes	yes	yes	yes	yes	no	novel	spurious
Composite prototype	yes	no	yes	no	not explicit	yes	no	both	true
Concept specialization	yes	yes	somewhat	somewhat	yes	yes	yes	both	spurious
Amalgam	yes	yes	yes	yes	no	yes	yes	both	both
Selective modification	yes	yes	no	no	Yes	no	yes	both	spurious
Fuzzy set	no	no	no	no	no	yes	yes	mundane	true

However, whenever we move to the linguistic level and use two words to denote a conceptual combination (e.g., “apartment dog”), it could be argued that the vast majority of empirically observed conceptual combinations, if not all, are really spurious conjunctives, because our intuitive understanding of the meaning of combination XY is usually very different from the meaning of YX. To repeat an earlier quote, “a desk lamp is a kind of lamp, but a lamp desk is a kind of desk” (Murphy, 2002 p.445). In the communicative context, syntactic constraints function by which one word sub-consciously functions as a logical operator X (i.e., the modifier) while the other word functions as a denotation Y (i.e., the head) such that X transforms Y into the denotation XY. Thus, when conceptual combinations are interpreted within a natural linguistic context and not defined artificially, it seems that there really are no genuine conjunctives and all combinations XY become so-called spurious conjunctives.

Another questionable implicit assumption made by most of the current models is that nouns represent concepts deserving of a rich schematic representation, while other parts-of-speech do not represent concepts and do not need to be represented by a similar cognitive structure. The earlier example of *apartment dog* showed that modifiers (*apartment*) are also rich concepts but, compared to head concepts, modifiers are treated by most theories in much simpler terms as mere slot fillers. In this example, the noun *apartment* acts as an adjective to modify the meaning of *dog*. In general, it is clear that concepts exhibit a greater variety of linguistic manifestations than just nouns, including adjectives, verbs, prepositions, adverbs, etc., which deserve an equally rich representation of their conceptual structure. If the modifier or non-noun component of a conceptual combination does more than just provide a value for a slot of the head noun concept, what might be the appropriate schematic representation of the modifier concept? How do the two schemata of the head and modifier concepts interact and influence one another in the interpretation of a conceptual combination? Future models of conceptual combination need to address these two questions.

CONCLUSION

Conceptual combination is a fundamental process of human cognition, in which people use two or more concepts to articulate and comprehend more complex meanings than a single concept can denote. Through conceptual combination we develop new ideas, communicate with one another, learn and expand our knowledge. This paper contributes to the study of conceptual combination by comprehensively and critically reviewing ten major models, which have been proposed over the last thirty years by researchers in cognitive psychology, linguistics, artificial intelligence, and philosophy. We have examined fuzzy set theory, the selective modification model, amalgam theory, the concept specialization model, the composite prototype model, the dual-process model, the constraint model, the CARIN model, coherence theory, and the interactive property attribution model. We have summarized the basic arguments of each model and critically examined their major issues and theoretical limitations. In addition, we proposed an analytical framework to compare and contrast the ten models along four dimensions: (1) the causal role of schemata in the model; (2) the role of cognitive harmony or consistency in the model; (3) the pragmatic orientation in the model; and (4) the explanatory scope of the model. We identified areas of agreement and

disagreement among the various models and theories. For example, all models assume a communicative purpose for the combination and a correspondence between linguistic words and psychological concepts. Most also agree that the component concepts (modifier or head) play different roles in the conceptual combination process, and interact with one another to generate a meaning in harmony with a person's background knowledge. Different models disagree substantially on the cognitive mechanisms involved, however, and emphasize different aspects of the process.

Finally, we have offered suggestions for future research directed toward the development of a synthesis model of the conceptual combination process. A suitable theory should address the limitations and problematic assumptions of schema theory as a representation of conceptual structure in online cognitive processing. It should accommodate the requirement for cognitive consistency by specifying both the cognitive mechanisms involved in reducing inconsistency and provide empirical methods for measuring the degree of consistency before and after combination. Pragmatic considerations should be integrated with cognitive considerations, such that background knowledge and aspects of the communicative and linguistic context of conceptual combination can be represented consistently with how concepts are represented. Lastly, a complete theory of conceptual combination must account for the diversity of combinations observed empirically (including both novel and mundane), accommodate the different roles of head and modify concepts in the combination process, reflect the conceptual complexity of the full range of linguistic parts-of-speech beyond just head nouns, and account for the interaction of complex head and modify concepts and their relative contribution to meaning during the combination process.

REFERENCES

- Barsalou, L. W. & Billman, D. (1989). Systematicity and semantic ambiguity. In Gorfain, D. (Ed.), *Resolving Semantic Ambiguity*. (pp. 146–203). New York: Springer-Verlag.
- Cannon G. (1987). Historical change and English word-formation. New York: Lang.
- Choi, Oh, Yi & Shin. (2007). A Model on the Processing of Noun-Noun Conceptual Combination and Its Verification. *IEEE Third International Conference on Natural Computation*. (ICNC 2007). Volume 5, 24-27.
- Cohen, B., & Murphy, G. L. (1984). Models of concepts. *Cognitive Science*. 8, 27-58.
- Costello, F., Estes, Z., Gagne C., & Wisniewski, E. (2004). PowerPoint presentation. *The Diversity of Conceptual Combination*. In. K Forbus, D Gentner & T Regier. (Ed), *Proceedings of the Cognitive Science Society*, Laurence Erlbaum.
- Costello, F. J. & Keane, M. T. (2001). Testing two theories of conceptual combination: Alignment versus diagnosticity in the comprehension and production of combined concepts. *Journal of Experimental Psychology: Learning, Memory and Cognition*. 27(1), 255-271.
- Costello, F. J. & Keane, M. T. (2000). Efficient creativity: Constraints on conceptual combination. *Cognitive Science*. 24, 299-349.
- Downing, P. (1977). On the creation and use of English compound nouns. *Language*. 53, 810-842.

- Estes, Z. & Glucksberg, S. (2000). Interactive property attribution in concept combination. *Memory & Cognition*. 28: 28-34.
- Fillmore, C. J. (1982). Frame semantics. In *Linguistics in the Morning Calm*. (pp. 111-137). Seoul: Hanshin Publishing Co.
- Fillmore, C. J. (1976). The case for Case reopened. In Cole, P. & Sadock, J. M., (Ed.), *Syntax and Semantics. Volume 8: Grammatical Relations*. (pp. 8 -22). New York: Academic Press.
- Fillmore C. J. (1968). The Case for Case. In Bach. & Harms. (Ed.), *Universals in Linguistic Theory*. (pp. 1-88). New York: Holt, Rinehart, and Winston.
- Gagné, C. L. (2001). Relation and lexical priming during the interpretation of noun noun combinations. *Journal of Experimental Psychology: Learning, Memory and Cognition*. 27, 236-254.
- Gagné, C. L. (2000). Relation-based versus property based combinations: A test of the CARIN theory and dual-process theory of conceptual combination. *Journal of Memory and Language*, 42, 365-389.
- Gagné, C. L., & Shoben, E. (2002). Priming relations in ambiguous noun-noun combinations. *Memory & Cognition*. 30, 637-646.
- Gagné, C. L., & Shoben, E. J. (1997). Influence of thematic relations on the comprehension of modifier-noun combinations. *Journal of Experimental Psychology: Learning, Memory and Cognition*. 23, 71-87.
- Gleitman, L. R., & Gleitman, H. (1970). *Phrase and paraphrase*. New York: Academic Press.
- Grice, Paul. (1975). Logic and conversation. In *Syntax and Semantics, 3: Speech Acts*. In P. Cole & J. Morgan. (Ed.), New York: Academic Press. Reprinted In H. P. Grice (Ed.), *Studies in the Way of Words*. (pp. 22-40). Cambridge, MA: Harvard University Press. (1989).
- Hampton, J. A. (1991). The combination of prototype concepts In. Schwanenflugel P. (Ed.), *The Psychology of word meanings*. Hillsdale, NJ. Lawrence Erlbaum Associates.
- Hampton, J. A. (1990). Conceptual combination: Conjunction and negation of natural concepts. *Unpublished manuscript*. London: City University.
- Hampton, J. A. (1989). Concepts and correct thinking. *Mind and Language*. 4, 35-42.
- Hampton, J. A. (1988). Disjunction of natural concepts. *Memory & Cognition*. 16, 579-591.
- Hampton, J. A. (1987). Inheritance of attributes in natural concept conjunctions. *Memory and Cognition*. 15(1), 55-71.
- Heider, F. (1960). The Gestalt theory of motivation. In M.R. Jones (Ed.), *Nebraska symposium on motivation Vol. VIII*, (pp. 145-172). Lincoln, Nebraska: University of Nebraska Press.
- Jones, G. (1982). Stacks not fuzzy sets: an ordinal basis for prototype theory of concepts. *Cognition*, 12. 281-291.
- Kay, P. & Zimmer, K. (1976). On the semantics of compounds and genitives in English. In *Sixth California Linguistics Association Proceedings*. San Diego. CA: Campile Press.
- Levi, J. N. (1978). *The Syntax and Semantics of Complex Nominals*. New York: Academic Press.
- Minsky, M. (1975). A framework for representing knowledge. In. Winston P. (Ed.), *The Psychology of Computer Vision*. (pp. 211-277). New York: McGraw Hill.
- Murphy, G. L. (2002). *The Big book of Concepts*. Cambridge MA: MIT Press.

- Murphy, G. L. (1990). Noun phrase interpretation and conceptual combination. *Journal of Memory and Language*. 29, 259-288.
- Murphy, G. L. (1988). Comprehending complex concepts. *Cognitive Science*. 12, 529-562.
- Murphy, G. L. (1982). Cue validity and levels of categorization. *Psychological Bulletin*. 91, 174-177.
- Osherson D. N. & Smith, E. E. (1982). Gradedness and conceptual combination. *Cognition*. 12, 299-318.
- Osherson D. N. & Smith, E. E. (1981). On the adequacy of prototype theory as a theory of concepts *Cognition*. 9, 35-58.
- Rumelhart, D. E. (1980). Schemata: The building blocks of cognition. In R. J. Spiro, B. C. Bruce , & W. F. Brewer (Ed.), *Theoretical issues in reading comprehension*. Hillsdale, NJ: Erlbaum.
- Rumelhart, D. E. & Ortony, A. (1977). The representation of knowledge in memory. In R.C. Anderson, R.J. Spiro, & W.E. Montague (Ed.) *Schooling and the acquisition of knowledge*. Hillsdale, NJ. Erlbaum.
- Smith, E. E., Osherson, D. N., Rips, L. J., & Keane, M. (1988). Combining prototypes: A selective modification model. *Cognitive Science*. 12, 485-527.
- Smith, E.E., & Osherson, D.N. (1984). *Categories and concepts*. Cambridge, MA: Harvard University Press
- Smith, E. E., Shoben, E. J. & Rips, L. J. (1974). Structure and process in semantic memory: A featural model for semantic decisions. *Psychological Review*. 1, 214-241.
- Simon D. & Holyoak K. (2002). Structural Dynamics of Cognition: From Consistency Theories to Constraint Satisfaction *Personality and Social Psychology Review*. 6 (6). 283-294
- Thagard, P., Verbeurgt, K. (1998). Coherence as Constraint Satisfaction. *Cognitive Science*. 22 (1) 1-24
- Thagard (1997). Coherent and Creative Conceptual Combination. In T. B. Ward, S. M. Smith, and J. Viad (Ed.), *Creative thought: an investigation of conceptual structures and processes*. Washington, DC. American Psychological Association (1997). Online version (<http://cogsci.uwaterloo.ca/Articles/Pages/CCCC.html>).
- Thagard, P. (1989). Explanatory coherence. *Behavioral and Brain Sciences*. 12: 435-467.
- Thagard, P. (1984). Conceptual combination and scientific discovery. In P. Asquith & P. Kitcher (Ed.), *PSA 1984*, vol. 1. (pp. 3-12). East Lansing: Philosophy of Science Association.
- Wisniewski, E. J. (1999). What makes a man similar to a Tie. *Cognitive Science*, 39, 208 – 238.
- Wisniewski, E. J., & Love, B. C. (1998). Relations versus properties in conceptual combination. *Journal of Memory and Language*. 38, 177-202.
- Wisniewski, E. J. (1997a). Conceptual combination: Possibilities and esthetics. In T.B. Ward, S. M. Smith, & J. Vaid (Ed.). *Creative thought: An investigation of conceptual structures and processes*. Washington DC: American Psychological Association.
- Wisniewski, E. J. (1997b). When concepts combine. *Psychonomic Bulletin and Review*. 4, 167-183.
- Wisniewski, E. J. & Markman, A. B. (1993). The role of structural alignment in conceptual combination. *Proceedings of the Fifteenth Annual Conference of the Cognitive Science Society*. Boulder, CO.

- Wisniewski, E.J., & Gentner, D. (1991). On the combinatorial semantics of noun pairs: Minor and major adjustments to meaning. In G. B. Simpson. (Ed.), *Understanding word and sentence*. Amsterdam: North Holland.
- Zadeh, L. (1982). A note on prototype theory and fuzzy sets. *Cognition*, 12(3), 291-298.
- Zadeh, L. (1976). A fuzzy-algorithmic approach to the definition of complex or imprecise concepts. *International Journal of Man-Machine Studies*. 8, 249-291.
- Zadeh, L. (1965). Fuzzy sets. *Information and Control*. 8, 338–353.

Chapter 12

A TEST OF THE COGNITIVE THEORY OF OBSESSIONS: STUDY OF INTERNAL STRUCTURE AND VALIDITY OF THE OBSESSIVE BELIEFS QUESTIONNAIRE IN ITALIAN INDIVIDUALS

***Stella Dorz^{1,4}, Caterina Novara¹, Massimiliano Pastore²,
Ezio Sanavio¹, Luigi Rocco Chiri³ and Claudio Sica³***

¹Department of General Psychology, University of Padova, Italy

²Department of Developmental and Social Psychology, University of Padova, Italy

³Department of Psychology University of Firenze, Italy

⁴Casa di Cura Parco dei Tigli, Private Clinic (Padova), Italy

ABSTRACT

Background: A widely-held belief is that obsessions arise from the misinterpretation of normal intrusive thoughts (e.g., misinterpreting unwanted harm-related thoughts as a sign that one is going to act on them). This leads the person to perform compulsions such as repeated checking. Misinterpretations are said to arise from various types of beliefs (e.g., the belief that thoughts inevitably give rise to actions). In support of this theory, some studies have shown that such beliefs are correlated with obsessive-compulsive disorder (OCD). The Obsessive Beliefs Questionnaire (OBQ) is an 87-item self-report instrument developed by an international group (Obsessive Compulsive Cognitions Working Group - OCCWG) to assess cognitions thought to be relevant to the etiology and maintenance of obsessions and compulsions. The OBQ contains six scales measuring as many dysfunctional beliefs: Inflated responsibility, Overimportance of thoughts, Excessive concern about the importance of controlling one's thoughts, Overestimation of threat, Intolerance of uncertainty, and Perfectionism. To date, the OBQ has been mainly studied in clinical and non-clinical individuals drawn from English-speaking populations. Results showed that the questionnaire generally has a good internal consistency

¹ Stella Dorz, Dipartimento di Psicologia Generale, University of Padua, via Venezia, 8, 35131 Padova, Italy (049-8276600) or Casa di Cura Parco dei Tigli, via Monticello, 1, 35037 Teolo-Padova, Italy (fax. 049-9997549). Email: stella.dorz@unipd.it

(Cronbach alpha coefficients equal or above .80) and an adequate test-retest reliability. However, three OBQ domains (Tolerance of uncertainty, Overestimation of threat and Perfectionism) appeared to be OCD-relevant but not OCD-specific, since they did not discriminate individuals with OCD from anxiety controls. In addition, correlations with measures of OCD symptoms, mood and worry, showed that the OBQ was as highly correlated with the non-OCD symptom measures (anxiety, depression and worry) as it was with OCD ones. Lastly, an exploratory factor analysis revealed that a three-factor solution best explained the internal structure of the questionnaire. In summary, such results raise doubts about the cognitive theory of obsessions and compulsions even though more studies are needed before the theory can be reformulated.

Aims and method: The present paper reports on the Italian validation of the OBQ: the extent to which the psychometric properties of the OBQ (and, in particular, its internal structure) are equivalent to the original one may reveal interesting clues about the structure of beliefs and their relationships with OCD symptoms. The OBQ was administered to 752 Italian undergraduate students along with the Padua Inventory (a measure of OCD symptoms), the Beck Anxiety Inventory and the Beck Depression Inventory.

Results: Exploratory factor analyses did not replicate the original six-factor structure of the OBQ, nor the three-factor structure obtained by analyzing the original American sample. A confirmatory factor analysis revealed that the Italian version of the OBQ was best described by five factors and 46 items. In particular, the Italian version was characterized by the absence of the intolerance of uncertainty and overestimation of threat scales, and by the subdivision of the responsibility scale into the scales responsibility for harm and responsibility for omission. Internal consistency and temporal stability of the five scales of Italian version of the OBQ was satisfactorily; intercorrelations among the five scales were moderately high. Results from convergent and discriminant validity revealed that Perfectionism, Responsibility for harm and Control thoughts resulted good predictors of OCD symptoms, whereas Responsibility of omission and Importance of thoughts did not predict OCD symptoms at all in a regression analysis model.

Findings were discussed in terms of relevance and specificity of cognitive constructs to OCD symptoms.

INTRODUCTION

The cognitive model of Obsessive Compulsive Disorder (OCD) has its origins in the theories formulated by A.T. Beck (1976). In summary, they posit the existence of cognitive structures, defined as schemas; various types of *disfunctional schemas* underlie different psychopathologies. A schema is defined as a thought structure which has been learned over time and which acts as a cognitive filter, directing attention and guiding the interpretation of experiences and events. When such schemas become overly rigid or active, it can lead to cognitive distortions, that is, to the systematic interpretation of present, past and future information according to certain faulty criteria, thereby producing emotional and cognitive disorders. Disfunctional schemas reveal themselves in certain beliefs and automatic thoughts.

As previously mentioned, the cognitive theory hypothesizes a schema-disorder correspondence, that is, the presence of certain specific schemas, and therefore typical beliefs, for certain psychopathological disorders. To illustrate, mood disorders are associated with beliefs regarding loss, failure and self-criticism (Beck, 1976: "I am worthless"); social phobia is viewed as arising from dysfunctional schemas associated with rejection and ridicule by

others (Beck, Emery e Greenberg, 1985: “being rejected is terrible”). Personality disorders, as well, are linked to different beliefs: dependent personality disorder would be underpinned by the conviction that “I can only feel good when there’s someone there to protect me”, borderline personality disorder would stem from various beliefs concerning the self and the outside world (“the world is a dangerous place”, “I cannot make it alone”, “the others cannot help me”; Beck, Freeman and Emery, 1990). But, what about OCD?

The cognitive theory of OCD has as its starting point the well-established finding that cognitive intrusions (i.e., thoughts, images, and impulses that intrude into consciousness) are experienced by most people (e.g., Salkovskis & Harrison, 1984). An important task for any theory is to explain why almost everyone experiences intrusions (at least at some point in their lives), yet only some people experience intrusions in the form of obsessions (i.e., intrusions that are unwanted, distressing, and difficult to remove from consciousness). Salkovskis argued that cognitive intrusions -- whether wanted or unwanted -- reflect the person’s current concerns. The concerns are automatically triggered by internal or external reminders. For example, intrusive thoughts of harm befalling others may be triggered by encountering potentially dangerous objects (e.g., the sight of sharp kitchen knives). Salkovskis proposed that intrusions develop into obsessions when intrusions are appraised as posing a threat for which the individual is personally responsible. To illustrate, consider the intrusive image of stabbing one’s child. Most people experiencing such an intrusion would regard it as a meaningless cognitive event – mental flotsam – with no harm-related implications. Such an intrusion would develop into an obsession only if the person were to appraise it as having serious consequences for which he or she is personally responsible. Likewise, compulsions are conceptualized as efforts to remove intrusions and to prevent any perceived harmful consequences. In addition to beliefs about personal responsibility, several other types of beliefs are thought to be important in producing obsessions and compulsions.

THE OBSESSIVE COMPULSIVE COGNITION WORKING GROUP (OCCWG)

In 1995, as part of a symposium realized during the International Congress of Cognitive-Behavioural Therapy (WCBCT, Denmark, July 1995), a group of academics, researchers and experts in OCD started to discuss the following questions: (1) which cognitive domains are central to OCD? (2) how can these domains be reliably measured? The discussion proved to be promising, and was so worthwhile that it provoked and stimulated further, numerous meetings.

The research group took on the name of OCCWG (Obsessive Compulsive Cognitions Working Group) and the instrument which, in time, it would develop, took the name of the Obsessive Beliefs Questionnaire (OBQ).

During the series of meetings that followed, the group identified, on the basis of clinical and theoretical knowledge, the cognitive domains (or beliefs) thought to be central to OCD. The idea was to develop an instrument capable of assessing these domains, to be used in both clinical and research contexts.. Five beliefs were initially identified as being relevant and centrally important: (1) inflated perception of responsibility, (2) thought-action fusion and other beliefs relative to the excessive importance attributed to thoughts, (3) excessive

importance attributed to the necessity of controlling one's own thoughts; (4) the overestimation of the likelihood of negative events occurring; (5) intolerance of uncertainty. A sixth domain, perfectionism, was subsequently added and was considered to be an important part of, though not unique, to OCD. A brief description of such domains is (OCCWG, 1997):

1. Inflated perception of responsibility: defined as a belief according to which the individual thinks she has the power to cause or prevent negative events. The prevention of these events is perceived as essential and they may have consequences both for the real world and at a moral level. Certain beliefs may concern the responsibility for errors of commission, as well as omission.
2. Importance of thought processes: defined as the belief that the mere presence of a thought can indicate that it is important. Other beliefs, such as those concerning magic thoughts and the fusion of thoughts and actions are part of this domain.
3. Control of thoughts: this domain reflects the importance of exercising complete control on one's own intrusive thoughts, impulses and mental images and the belief that this is both possible and desirable. Four other subdomains were identified: (a) the importance of monitoring one's mental life; (b) the belief that there are moral consequences if one's thoughts are not controlled; (c) the belief that there are psychological consequences when one fails to control one's thoughts; (d) the belief that efforts to control one's own thoughts should be successful.
4. Overestimation of threat: defined as the esageration of the gravity of a possibly harmful event.
5. Intolerance of uncertainty: characterized by three types of beliefs: (a) the belief that it is necessary to be certain of decisions taken; (b) the belief that one has limited capacities in the face of unforeseen changes; (c) the belief that ambiguous situations are difficult to deal with.
6. Perfectionism: in relation to OCD, it was defined as the tendency to believe that there is a perfect solution for every problem, that doing things perfectly is not only possible but necessary and that even small problems can have serious consequences.

DEVELOPMENT OF THE OBSESSIVE BELIEFS QUESTIONNAIRE (OBQ)

The Obsessive Beliefs Questionnaire is composed of 87 items, divided into six subscales, which reflect the beliefs identified by the OCCWG (1997, 2001). The questionnaire respondents are asked to indicate the degree to which they agree with each of the phrases using a 7-point Likert scale which varies from 1 (not at all in agreement) to 7 (completely in agreement). The scales are: (a) control of thoughts, 14 items; (b) importance of thoughts, 14 items; (c) responsibility, 16 items; (d) intolerance of uncertainty, 13 items; (e) overestimation of threat, 14 items e (f) perfectionism, 16 items. The score for each scale is calculating by summing each of the items.

The measure underwent a procedure of validation mainly using samples from the USA. An initial study conducted by the group (OCCWG, 2003) on large clinical (248 patients with OCD, 105 patients with anxiety disorders without OCD) and non-clinical samples (87 non-

clinical adults and 291 university students) investigated internal consistency, test-retest reliability and criterion, convergent and discriminant validity. While the analyses produced optimal levels of internal consistency and temporal stability for all the scales (Cronbach's alpha values ranged from .87 for the control of thoughts scale to .93 for the perfectionism scale; temporal stability, measured over an interval of two months, varied between .48 for the control of thoughts scale and .83 for the perfectionism scale), results concerning indicators of validity were not as satisfactory. The OCD group scored significantly more highly on all scales as compared to the normal subjects, but when compared to the clinical non-OCD group there were significant differences only on three of the six scales (responsibility, control of thoughts, importance of thoughts). Convergent validity analyses resulted in moderate correlations between the six scales of the OBQ and the other OCD symptom measures (with the exception of the importance of thoughts scale); moreover, the correlations between the OBQ scales and the measures of general distress (e.g. anxiety, depression, worry) were approximately similar to those with the OCD symptom measures. Lastly, the intercorrelations between the various dimensions of the OBQ were fairly high, indicating a degree of overlap between the various constructs measured.

Other studies on samples in different countries confirmed doubts regarding the psychometric properties of the OBQ. Sica and colleagues (2004) compared 43 Italian individuals with obsessive-compulsive disorder (OCD), 17 with generalized anxiety disorder (GAD) and 50 non-clinical controls (SC), using the OBQ and various measures of obsessive-compulsive symptoms, depression, anxiety and worry. Overall, three cognitive domains out of six (intolerance of uncertainty, control of thoughts and perfectionism) discriminated OCD from GAD and non-clinical controls, whereas overimportance of thoughts and inflated responsibility barely discriminated clinically anxious individuals from non-clinical ones. An additional domain, overestimation of threat, did not discriminate OCD from GAD. In addition, in a study on French-speaking individuals, the six factor structure of the OBQ was not replicated (Careau, O'Connor, Turgeon, & Freeston, 2003).

In general, therefore, the original OBQ scales, in addition to a notable degree of intercorrelation in the original American studies, have not always proved to have discriminative power. Furthermore, it was not clear if the internal structure of the instrument reflected the theoretical premises upon which it had been built.

All these elements might effectively indicate an overlap between the cognitive domains and their ill-defined differentiation and specificity. Further analysis and development of the instrument were indispensable at that point. The OBQ, therefore, needed to be reassessed and revised, reducing the pool of items and redefining the structure and their underlying constructs (OCCWG, 2005).

A factor analytic model was used to investigate the factorial structure of the OBQ. A total of 410 American outpatients diagnosed with OCD completed the OBQ and a battery of questionnaires assessing OCD, depressive and anxiety symptoms. For comparisons, the answers from the same non-OCD samples of the 2003 study (105 non-obsessional anxious patients, 87 non-clinical adults from community and 291 undergraduate students) were utilized.

The exploratory factor analysis provided evidence of a three-factor structure (which explained 42% of the variance). The first scale, made up of 8 items from the threat estimation scale and 8 from the responsibility scale, was defined as the *Responsibility/Threat Estimation scale* (16 items). It is concerned with the necessity of preventing negative consequences for

oneself or others, the responsibility for and consequences of inactivity (e.g. “negative events are less likely to occur if I’m careful”, “I think that not preventing danger is as bad as causing it”). The second scale, called *Perfectionism/Certainty* (16 items) is made up of 12 items of the perfectionism scale and 4 items from the intolerance of uncertainty scale. It measures the presence of a high degree of rigidity, reflection on errors and feelings of uncertainty. (e.g. “I don’t think things are ok unless they’re perfect”, “I must be absolutely certain of each of my decisions”). Lastly, the third scale is defined as *Importance/Control of thoughts* and includes 9 items from the importance of thoughts scale and 3 from the control of thoughts scale, resulting in a total of 12 items. The items concern the consequences of experiencing unacceptable and intrusive thoughts or mental images, the fusion of thoughts and actions, and the necessity to control each thought. (e.g. “having negative thoughts means that I’m not normal”).

The final version is therefore composed of 44 items (named OBQ-44) subdivided into 3 scales. Such version had very good levels of internal consistency (respectively $\alpha=.93$, $.93$ and $.89$). Comparing the various groups, OCD individuals obtained scores significantly higher than non-OCD individuals on the Responsibility/Estimation of Danger scale and on the Importance/Control of thoughts scale, but not on the Perfectionism/Certainty scale. In all the comparisons, OCD and non-OCD patients obtained scores significantly higher than normal groups. Overall, results indicated a superior convergent and discriminant validity in comparison with the 87-item version. Lastly, regression analyses have shown that this version of the OBQ is predictive of OCD symptoms even after measures of general distress (depression and anxiety) have been controlled for (OCCWG, 2005).

Aims of the Current Study

A key element of any psychological measure is content validity (an important component of construct validity) because it provides evidence about the degree to which the elements of the assessment instrument are relevant to, and representative of, the targeted construct(s) (Haynes, Richard and Kubany, 1995). However, domains and facets of many constructs change over time and across contexts; in other words, the relevance and representativeness of the elements of a self-report measure are unstable and conditional in nature (De Vellis, 1991; Ebel and Frisbie, 1991). As a consequence, validity should be established when the instrument is used with cultural groups on which it has not been standardized. Without evidence of translation and psychometric adequacy, and appropriate normative data, the use of assessment instruments with different cultural groups remains problematic (Kinzie and Manson, 1987). Furthermore, studies on different cultural groups may help to refine the theoretical constructs themselves.

The present study has therefore two main aims: a) investigating the psychometric characteristics of the OBQ. Since the instrument was developed in the USA, it requires an in-depth analysis to demonstrate its reliability and validity with an Italian population. In fact, as we will see, our study shows that the Italian version of the OBQ cannot be considered equivalent to the original one; b) stressing the limits of cognitive constructs thought to be related to OCD, limits already emerged in the original studies of the OBQ.

In this way we hope to contribute to the advancement of our knowledge about the cognitive components of OCD.

Since a previous Italian study has already ascertained the psychometric characteristics of the OBQ in clinical patients (Sica et al., 2004), we elected to enroll a large sample of non-clinical individuals in order to study the internal structure of the questionnaire through factor analytic strategies. Indeed, it is almost impossible to find in Italy clinical samples of the required size, given the low prevalence of the OCD in the general population (about 1-2%). Moreover, a plethora of research has shown that non-clinical subjects experience OCD phenomena, albeit with less intensity and distress compared to clinical subjects (e.g., Burns, Formea, Keortge, & Sternberger, 1995; Salkovskis & Harrison, 1984; Sterneberger & Burns, 1990). Hence, there is widespread use of non-clinical samples in the investigation of OCD (for a critical review, see Gibbs, 1996).

METHOD

Participants and Procedure

The data used in this validation study come from two research phases, the first occurred between June and September 2002, with the recruitment of a total of 412 subjects from the student population (the psychology and engineering faculties, University of Padova, Northern Italy). In accordance with the most recent methodological procedures - which suggest the exclusion of participants with psychopathological characteristics from non-clinical samples - 37 subjects were excluded on the basis of their scores on the Padua Inventory (a widely used measure of OCD symptoms).

A further 11 subjects, who did not complete all items of the OBQ, were also excluded. The final sample was therefore composed of 364 subjects (44% females), with a mean age of 21.2 (SD=2.4) and 14.1 years of education (SD=2.1). The second phase of data collection involved 388 subjects (psychology faculty, University of Padova) who completed the questionnaire battery between March and June 2005. Two subjects who had not completed all of the items were excluded from the sample. The final sample was therefore made up of 386 subjects (82.1% females), mean age =20.2 (SD=2.8), years of schooling=13.9 (SD=0.8).

Two comparisons were conducted which verified the overlap between the variables of age (21.2 vs 20.2, $F_{(1,750)}=1.5$, NS) and years of school (14.1 vs 13.9, $F_{(1,744)}=1.3$, NS) between the two samples. There was a higher percentage of female students in the second sample as compared with the first (44% vs 82.1%). The final sample was composed of 752 subjects (63.4% females), with a mean age of 20.7 (SD=2.6; range 18-43), with 13.9 years of schooling, and mostly not married ($n=735$, 97.7%).

Eligible participants were requested to complete a battery of self-report measures. Administration of measures was undertaken in groups and the sequence of measures was rotated in order to control for order effects. A psychologist was always available to respond to requests for clarification. All individuals participated on a voluntary basis and gave their written consent before taking part.

MEASURES

Translation of the OBQ

The Italian version of the Obsessive Beliefs Questionnaire was developed by the Italian group through the following steps:

- (1) three independent translations of the original questionnaire (87 items) by three members of the group
- (2) comparison of the three translations and discussion of the points of disagreement in order to decide on a single version,
- (3) back-translation completed by a native speaker of English,
- (4) comparison of the original English version and the back-translation in order to identify any incongruencies or differences in meaning,
- (5) adaptations and modifications of form in order to facilitate the comprehension and reading of the text,
- (6) pilot administration on small groups taken from the non-clinical population in order to verify comprehensibility and legibility, (7) further modifications and final improvements.

Other Measures of Psychopathology

The *Padua Inventory* (PI; Sanavio, 1988) is a 60-item self-report instrument developed in Italy, assessing OCD symptoms using a total scale and four subscales: Impaired Mental Control, Contamination, Checking, Urges and Worries. In the original study (Sanavio, 1988), using an Italian normative sample of 828 subjects of varying ages, the total scale demonstrated very good internal consistency (Cronbach's $\alpha = .94$); Cronbach's alpha coefficients ranged from .70 to .90 for the four subscales. A 4-week retest reliability coefficient for the total scale was calculated for males (.84) and for the female sample (.86). The *Beck Anxiety Inventory* (BAI; Beck, Epstein, Brown & Steer, 1988) is a 21-item self-report inventory that measures the severity of anxiety, focusing predominantly on physiological aspects of anxiety. Beck et al. (1988) reported excellent internal consistency (Cronbach's $\alpha = .92$) and a 1-week retest reliability coefficient of .75. The Italian version of the BAI was administered to 654 undergraduates, 831 community controls and 64 anxious patients.

The findings indicated good internal consistency (Cronbach's $\alpha = .89$) and a 30-day retest reliability of .62, as well as good convergent, divergent, and criterion validity (Sica & Ghisi, 2007). The *Beck Depression Inventory* (BDI; Beck & Steer, 1987). It is a widely used 21-item self-report inventory that measures the presence and severity of depression. The Italian version of the BDI was administered to 900 Italian adults (Centomo & Sanavio, 1992). The findings indicated good internal consistency (Cronbach's $\alpha = .82$) and a 30-day retest reliability of .74.

RESULTS

Three-Factor Solution

Given that the final version of the OBQ seems to have a three-factor internal structure, (OCCWG, 2005) we wanted to verify the suitability of this model for use with the Italian population.

A maximum likelihood factor analysis with varimax rotation (three factors) was performed. The Kaiser-Meyer-Olkin index was 94.2. The three-factor solution explained 31.5% of the variation. The eigenvalues for the three factors are: 20.1, 3.7 and 3.5. Table 1 reports the factorial loadings of the items.

Table 1. Factor Loading of the Obq Items (Three Factors Solution)

Item n°	ITEM	scale	I	II	III
86	If I don't control my thoughts, I'll be punished	C	.63		
75	Being unable to control unwanted thoughts will make me physically ill	C	.62		
15	I can have no peace of mind as long as I have intrusive thoughts	C	.57		
54	To avoid disasters, I need to control all the thoughts or images that pop into my mind	C	.56		
69	Having intrusive thoughts means I'm out of control	C	.54		
72	Harmful events will happen unless I am very careful	TE	.54	.30	
76	Having violent thoughts means I will lose control and become violent	IP	.52		
18	The more I think of something horrible, the greater the risk it will come true	IP	.52		
64	Having bad thoughts means I am weird or abnormal	IP	.51		
14	The more distressing my thoughts are, the greater the risk that they will come true	IP	.51		
5	If I don't control my unwanted thoughts, something bad is bound to happen	C	.50		
61	I am more likely than other people to accidentally cause harm to myself or to others	TE	.49	.34	
77	To me, failing to prevent a disaster is as bad as causing it	R	.48		
29	I must be ready to regain control of my thinking whenever an intrusive thought or image occurs	C	.47		.36
50	If I do not take extra precautions, I am more likely than others to have or cause a serious disaster	TE	.47		
59	I should be able to rid my mind of unwanted thoughts	C	.47		
12	I would be a better person if I gained more control over my thoughts	C	.46		
46	Having nasty thoughts means I am a terrible person	IP	.46		
41	For me, not preventing harm is as bad as causing harm	R	.44		
38	In all kinds of daily situations, failing to prevent harm is just as bad as deliberately causing harm	R	.43		
58	Having a blasphemous thought is as sinful as committing a sacrilegious act	IP	.43		
17	I must know what is going on in my mind at all times so I can control my thoughts	C	.42		.32
49	Thinking about a good thing happening can prevent it from happening	IP	.41		

Table 1. (Continued)

Item n°	ITEM	scale	I	II	III
79	Even ordinary experiences in my life are full of risk	TE	.41		
23	Even if harm is very unlikely, I should try to prevent it at any cost	R	.41		.39
82	When anything goes wrong in my life, it is likely to have terrible effects	TE	.41	.31	
16	Things that are minor annoyances for most people seem like disasters for me	TE	.40	.32	
24	For me, having bad urges is as bad as actually carrying them out	IP	.38		
37	If I have an intrusive thought while I'm doing something, what I'm doing will be ruined	C	.37		
68	Even when I am careful, I often think that bad things will happen	TE	.37	.32	.37
8	Whenever I lose control of my thoughts, I must struggle to regain control	C	.37		
7	When I hear about a tragedy, I can't stop wondering if I am responsible in some way	R	.36		
81	If I take sufficient care, I can prevent any harmful accident from occurring	R	.33		
34	If I have aggressive thoughts or impulses about my loved ones, this means I may secretly want to hurt them	IP	.33		
55	I should not have bizarre or disgusting thoughts	IP	.33		
3	If I am uncertain, there is something wrong with me	TI	.32	.32	
83	Having a bad thought is morally no different than doing a bad deed	IP	.31		
48	If an intrusive thought pops into my mind, it must be important	IP			
66	Having an unwanted sexual thought or image means I really want to do it	IP			
2	Having control over my thoughts is a sign of good character	C			
1	Having bad thoughts or urges means I'm likely to act on them.	IP			
51	If I don't do as well as other people, that means I am an inferior person	P		.72	
78	If I don't do a job perfectly, people won't respect me	P		.72	
56	For me, making a mistake is as bad as failing completely	P		.70	
22	If I fail at something, I am a failure as a person	P		.70	
36	If someone does a task better than I do, that means I failed the whole task	P		.70	
19	In order to be a worthwhile person, I must be perfect at everything I do	P		.64	
84	No matter what I do, it won't be good enough	P		.64	
45	For me, things are not right if they are not perfect	P		.64	
28	If I can't do something perfectly, I shouldn't do it at all	P		.59	
13	Things should be perfect according to my own standards	P		.56	
80	When things go too well for me, something bad will follow	TE	.30	.46	
40	Small problems always seem to turn into big ones in my life	TE	.32	.45	
70	It is terrible to be surprised	TI		.44	
30	Bad things are more likely to happen to me than to other people	TE	.40	.44	
87	I need the people around me to behave in a predictable way	TI		.44	
63	If something unexpected happens, I will not be able to cope with it	TI	.30	.43	
65	I must be the best at things that are important to me	P		.42	.39
85	I often think that I will be overwhelmed by unforeseen events	TI	.36	.42	
47	I often believe I am responsible for things that other people don't think are my fault	R	.31	.37	.32

Item n°	ITEM	scale	I	II	III
26	If an unexpected change occurs in my daily life, something bad will happen.	TI		.36	
9	I am much more likely to be punished than are others	TE	.30	.36	
42	I should be upset if I make a mistake	P		.32	
10	If I'm not absolutely sure of something, I'm bound to make a mistake	TI		.32	
11	There is only one right way to do things	P			
43	I should make sure others are protected from any negative consequences of my decisions or actions	R			.61
32	It is essential for me to consider all possible outcomes of a situation	TI			.60
57	It is essential for everything to be clear cut, even in minor matters	TI			.58
25	I must think through the consequences of even my smallest actions	R			.56
71	Even if harm is very unlikely, I should try to prevent it at any cost	R	.30		.56
31	I must work to my full potential at all times	P			.54
53	In order to feel safe, I have to be as prepared as possible for anything that could go wrong	TI		.31	.53
21	It is ultimately my responsibility to ensure that everything is in order	R			.52
74	I must keep working at something until it's done exactly right	P		.45	.51
20	When I see any opportunity to do so, I must act to prevent bad things from happening	R			.50
62	For me, even slight carelessness is inexcusable when it might affect other people	R			.49
33	Even minor mistakes mean a job is not complete	P			.49
67	If my actions could have even a small effect on a potential misfortune, I am responsible for the outcome	R			.49
73	I should go to great lengths to get all the relevant information before I make a decision.	TI			.49
35	I must be certain of my decisions	TI			.45
39	Avoiding serious problems (e.g., illness or accidents) requires constant effort on my part	TE	.35		.44
44	If I exercise enough will-power, I should be able to gain complete control over my mind	C			.42
52	I believe that the world is a dangerous place	TE			.40
6	I often think things around me are unsafe	TE			.39
60	I should be 100% certain that everything around me is safe	TI		.38	.38
27	If I don't act when I foresee danger, then I am to blame for any consequences	R	.30		.34
4	If I imagine something bad happening, then I am responsible for making sure it doesn't happen	R			.33

TE= Threat estimation; TI= Tolerance for uncertainty ; IP= Importance of thoughts;

C= Control of thoughts; R=Inflated responsibility; P= Perfectionism;

Factor loadings > .30 are reported.

The first factor is composed by items which belong to control of thoughts scale (n=12), importance of thoughts (n=11), overestimation of threat (n=7, but with factor loading < .5) and responsibility (n=6, but with factor loading < .49) and corresponds to the Importance/Control of Thought scale of the OBQ-44. All the items of the original Importance/Control of Thought scale load onto this factor, even if they have coefficients below .5; however, items with higher loadings are not part of the original scale (i.e. items 86, 75, 15, 54, 69, 72).

The second factor corresponds to the Perfectionism/Certainty scale (OBQ-44) and is composed of items from perfectionism (n=13), intolerance of uncertainty (n=9) and overestimation of threat (n=9). All the items with factor loadings above .50 are part of the 44-

item OBQ scale, and come from the original perfectionism scale (OBQ-87). Items 31, 33 and 74, which in theory should belong to this scale, load onto factor three. Item 11 did not have factor loadings of above .3 on any of the resultant factors.

The third factor corresponds to the Responsibility/Threat scale (OBQ-44) and is composed of items from responsibility ($n=9$), intolerance of uncertainty ($n=6$) and, to a smaller degree, by items from overestimation of threat. Numerous differences make comparison difficult with the original scale of the OBQ-44.

In conclusion, the internal structure of the Italian version of the OBQ presents substantial differences compared to that identified in the original American version (OBQ-44). A different conceptualisation of the structure of the cognitive domains in the Italian population must therefore be considered.

EXPLORATIVE FACTOR ANALYSIS: SIX-FACTOR SOLUTION

Since the structure found in the American version was not replicated, in order to study the internal structure of the Italian version of the OBQ, an explorative factor analysis was employed. The maximum likelihood method with varimax rotation was used. The number of factors to take into consideration was decided on the basis of: (1) a scree test (Cattell, 1966); (2) the simplicity of the structure and (3) the interpretability.

The application of these criteria led to a six-factor solution (see Table 2), which explains 39.6% of the variance. The eigenvalues for the six factors are: 19.04, 4.26, 3.60, 3.09 e 2.38. The Kaiser-Meyer-Olkin goodness-of-fit index was .885, indicating that the correlation matrix is acceptable for factor analysis (Tabachnick e Fidell, 1996).

Factor I has high loadings from items that measure perfectionism ($n=13$) and items from the intolerance of uncertainty scale ($n=5$), which are mainly focused on the predictability of events (e.g. item 70: "I can't stand unexpected things happening to me"). It seems to be a type of perfectionism that is extended to future events, or else to a willful control of events, both present and future.

Factor II includes, above all, items from responsibility ($n=10$) and intolerance of uncertainty ($n=5$), but also four items which measure perfectionism and one item each from overestimation of threat and intolerance of uncertainty. However, both the items from responsibility and those from intolerance of uncertainty are focused on making safe decisions and on the desire that no harm be done to others. (e.g. from the responsibility scale: "I have to be sure that others won't suffer harm because of my decisions", from intolerance of uncertainty: "Before making decisions I should spend time gathering all available information"). The remaining items are more difficult to interpret and also have high loadings on other factors, or very low loadings on all factors.

Factor III is composed of items from overestimation of threat ($n=9$), from importance of thoughts ($n=3$), from control of thoughts ($n=3$) and from intolerance of uncertainty ($n=2$) plus one from responsibility. The first two groups of items seem to be focused on the idea of the world as a dangerous place and that merely thinking negatively can increase the chance of something bad happening. The remaining ones are more difficult to interpret or have high loadings on other factors.

Factor IV is mainly made up of items from control of thoughts (n=11) with one item, the presence of which is difficult to explain, from intolerance of uncertainty.

Factor V is composed of items from responsibility (n=5), from overestimation of threat (n=3) and from importance of thoughts (n=3). The items from importance of thoughts also have high loadings on factor III. The other items, in contrast, are focused on the idea that it is necessary to prevent harmful events. It seems therefore that the concept of responsibility is divided into responsibility for harm (factor II) and omission (this factor).

Factor VI is made up of items belonging to the importance of thoughts scale (n=7). The items are concerned with the fusion of actions and thoughts but, in contrast to items from factor III, regard self-evaluation: "having bad thoughts means I'm a bad person".

In summary, the six-factor structure of the 87-item OBQ is not entirely clear and does not reflect the cognitive domains upon which the instrument was constructed.

Table 2. Factor loading of the OBQ items (six factors solution)

Item n°	ITEM	subscale	I	II	III	IV	V	VI
45	For me, things are not right if they are not perfect	P	.70					
78	If I don't do a job perfectly, people won't respect me	P	.68					
19	In order to be a worthwhile person, I must be perfect at everything I do	P	.67					
36	If someone does a task better than I do, that means I failed the whole task	P	.66					
22	If I fail at something, I am a failure as a person	P	.65					
56	For me, making a mistake is as bad as failing completely	P	.63					
51	If I don't do as well as other people, that means I am an inferior person	P	.63					
28	If I can't do something perfectly, I shouldn't do it at all	P	.62					
13	Things should be perfect according to my own standards	P	.62					
84	No matter what I do, it won't be good enough	P	.48		.48			
74	I must keep working at something until it's done exactly right	P	.47	.44				
70	It is terrible to be surprised	TI	.43					
65	I must be the best at things that are important to me	P	.43					
26	If an unexpected change occurs in my daily life, something bad will happen.	TI	.42					
60	I should be 100% certain that everything around me is safe	TI	.39					
11	There is only one right way to do things	P	.39			.34		
87	I need the people around me to behave in a predictable way	TI	.37					
10	If I'm not absolutely sure of something, I'm bound to make a mistake	TI	.34					
43	I should make sure others are protected from any negative consequences of my decisions or actions	R		.69				
32	It is essential for me to consider all possible outcomes of a situation	TI		.60				
25	I must think through the consequences of even my smallest actions	R		.56				

Table 2 (Continued)

Item n°	ITEM	subscale	I	II	III	IV	V	VI
71	Even if harm is very unlikely, I should try to prevent it at any cost	R		.54				
21	It is ultimately my responsibility to ensure that everything is in order	R		.53				
67	If my actions could have even a small effect on a potential misfortune, I am responsible for the outcome	R		.51				
33	Even minor mistakes mean a job is not complete	P		.51				
73	I should go to great lengths to get all the relevant information before I make a decision.	TI		.51				
20	When I see any opportunity to do so, I must act to prevent bad things from happening	R		.51				
53	In order to feel safe, I have to be as prepared as possible for anything that could go wrong	TI		.49				
39	Avoiding serious problems (e.g., illness or accidents) requires constant effort on my part	TE		.49				
62	For me, even slight carelessness is inexcusable when it might affect other people	R		.49				
57	It is essential for everything to be clear cut, even in minor matters	TI		.49				
31	I must work to my full potential at all times	P		.46				
68	Even when I am careful, I often think that bad things will happen	TE		.42	.38			
27	If I don't act when I foresee danger, then I am to blame for any consequences	R		.41				
35	I must be certain of my decisions	TI		.37				
23	Even if harm is very unlikely, I should try to prevent it at any cost	R		.37				
4	If I imagine something bad happening, then I am responsible for making sure it doesn't happen	R		.34				
48	If an intrusive thought pops into my mind, it must be important	IP		.29	.24			
42	I should be upset if I make a mistake	P		.22	.21			
85	I often think that I will be overwhelmed by unforeseen events	TI			.65			
16	Things that are minor annoyances for most people seem like disasters for me	TE			.65			
40	Small problems always seem to turn into big ones in my life	TE			.62			
30	Bad things are more likely to happen to me than to other people	TE			.57			
80	When things go too well for me, something bad will follow	TE			.55			
47	I often believe I am responsible for things that other people don't think are my fault	R			.55			
61	I am more likely than other people to accidentally cause harm to myself or to others	TE			.49			
18	The more I think of something horrible, the greater the risk it will come true	IP			.48			
52	I believe that the world is a dangerous place	TE		.41	.46			
6	I often think things around me are unsafe	TE		.40	.45			
79	Even ordinary experiences in my life are full of risk	TE			.43			

Item n°	ITEM	subscale	I	II	III	IV	V	VI
14	The more distressing my thoughts are, the greater the risk that they will come true	IP			.42			
86	If I don't control my thoughts, I'll be punished	C			.42	.30	.33	
9	I am much more likely to be punished than are others	TE			.41		.30	
75	Being unable to control unwanted thoughts will make me physically ill	C			.41	.36		
63	If something unexpected happens, I will not be able to cope with it	TI			.40			
8	Whenever I lose control of my thoughts, I must struggle to regain control	C			.38			
49	Thinking about a good thing happening can prevent it from happening	IP			.38			
12	I would be a better person if I gained more control over my thoughts	C			.30	.58		
2	Having control over my thoughts is a sign of good character	C				.57		
29	I must be ready to regain control of my thinking whenever an intrusive thought or image occurs	C				.53		
44	If I exercise enough will-power, I should be able to gain complete control over my mind	C		.36		.51		
15	I can have no peace of mind as long as I have intrusive thoughts	C				.50		
59	I should be able to rid my mind of unwanted thoughts	C				.48		
5	If I don't control my unwanted thoughts, something bad is bound to happen	C				.47		
17	I must know what is going on in my mind at all times so I can control my thoughts	C				.46		
3	If I am uncertain, there is something wrong with me	TI				.46		
69	Having intrusive thoughts means I'm out of control	C				.39		
37	If I have an intrusive thought while I'm doing something, what I'm doing will be ruined	C				.37		
54	To avoid disasters, I need to control all the thoughts or images that pop into my mind	C				.34		
38	In all kinds of daily situations, failing to prevent harm is just as bad as deliberately causing harm	R					.61	
77	To me, failing to prevent a disaster is as bad as causing it	R					.57	
41	For me, not preventing harm is as bad as causing harm	R		.33			.56	
50	If I do not take extra precautions, I am more likely than others to have or cause a serious disaster	TE			.37		.47	
82	When anything goes wrong in my life, it is likely to have terrible effects	TE			.34		.43	
72	Harmful events will happen unless I am very careful	TE			.30		.40	
76	Having violent thoughts means I will lose control and become violent	IP			.30		.40	
34	If I have aggressive thoughts or impulses about my loved ones, this means I may secretly want to hurt them.	IP					.39	
66	Having an unwanted sexual thought or image means I really want to do it	IP					.36	

Table 2 (Continued)

Item n°	ITEM	subscale	I	II	III	IV	V	VI
81	If I take sufficient care, I can prevent any harmful accident from occurring	R					.36	
7	When I hear about a tragedy, I can't stop wondering if I am responsible in some way	R					.29	
58	Having a blasphemous thought is as sinful as committing a sacrilegious act	IP						.63
55	I should not have bizarre or disgusting thoughts	IP						.62
24	For me, having bad urges is as bad as actually carrying them out	IP						.60
46	Having nasty thoughts means I am a terrible person	IP						.54
83	Having a bad thought is morally no different than doing a bad deed	IP						.53
64	Having bad thoughts means I am weird or abnormal	IP			.34			.42
1	Having bad thoughts or urges means I'm likely to act on them.	IP						.24

TE= Threat estimation; TI= Tolerance for uncertainty ; IP= Importance of thoughts;

C= Control of thoughts; R=Inflated responsibility; P= Perfectionism;

Factor loadings >.30 are reported.

CONFIRMATIVE FACTOR ANALYSIS

Since the previous analyses did not reveal a satisfactory internal structure for the OBQ, the six-factor structure emerging from the explorative factor analysis was subjected to a confirmative factor analysis in order to assess the goodness-of-fit of the model to the data.

In contrast with the explorative factor analysis, the aim of which is simply to identify the factor structure given the set of variables, the confirmative analysis tests a hypothesized factor structure or model, and evaluates its goodness-of-fit with the data. Confirmative factor analysis (CFA) could be seen as an underlying model of the more general approach of analysis defined as the of model of structural equations. The hypothesized model was tested with LISREL 8.30 (Jöreskog e Sörbom, 1996).

The analysis was conducted in the following stages: (1) on the basis of the results of the explorative factor analysis, each of the six factors was singularly subjected to confirmative analysis; (2) if the factor did not adequately explain the data, then items were excluded on the basis of statistical and theoretical considerations and the model was retested until the goodness-of-fit criteria had been met. The sample of 752 subjects was utilized.

As suggested by various authors (Beckstead, 2002; Browne e Cudeck, 1993; Hu e Bentler, 1999) the goodness-of-fit of the model (in our case, of single factors to the data) was evaluated in relation to various indices of fit: RMSEA (Root Mean Square Error Of Approximation, acceptable for values under .06), GFI (Goodness of Fit Index, acceptable for values above .9), AGFI (Adjusted Goodness of Fit Index, acceptable for values above .9), and CFI (Comparative Fit Index, acceptable for values above .9).

The first factor, defined as Perfectionism, was initially evaluated by taking into consideration all 18 items which had emerged from the previous explorative analysis. Either

because they did not improve goodness-of-fit, or on the basis of theoretical considerations, items 26, 70, 10, 60, 87, 36, 65 were excluded (all belonging to the intolerance of uncertainty scale). The final scale is therefore composed of 11 items: 11, 13, 19, 28, 33, 45, 51, 65, 74, 78, 84. All were already present in the scale of origin (OBQ-87). The model has adequate goodness-of-fit indices: RMSEA=0.076; GFI=0.936; AGFI=0.904; CFI=0.926.

The second factor tested, defined as Responsibility for harm, was composed of 21 items from various scales. Items 20, 23, 27, 31, 33, 35, 60, 73 were excluded as they do not increase goodness-of-fit. Items 39, and 68 (from overestimation of threat), and 53 (from intolerance of uncertainty) were retained since, from a theoretical point of view, they refer to the concept of responsibility which is central to the theory. The final scale is composed of 10 items: 4, 21, 25, 39, 43, 53, 62, 67, 68, 71. All items were already present in the scale of the OBQ-87. The model has good indices of goodness-of-fit: RMSEA=0.0474; GFI=0.975; AGFI=0.963; CFI=0.966.

Overestimation of Threat: items belonging to various scales load highly onto this factor, including overestimation of threat and the importance of thoughts. Various attempts were made to verify the goodness-of-fit of the model to the available data, in particular by evaluating an overestimation of threat dimension. In the end, no version of the model produced satisfactory goodness-of-fit indices and this factor was therefore excluded.

Control of thoughts: factor four corresponds to the domain of control of thoughts with high loadings by 12 items: 2, 3, 5, 12, 15, 17, 29, 37, 44, 54, 59, 69 all originally belonging to scale control of thoughts with the exception of item 3 which belongs to the intolerance of uncertainty. Goodness-of-fit was tested with unsatisfactory results: RMSEA=0.073, GFI=0.881, AGFI=0.918, CFI=0.882. The weakest item was item 3, which was excluded, partly also for theoretical reasons. The model was then retested. This new model appears to fit the data well: RMSEA=0.068, GFI=0.902, AGFI=0.929, CFI=0.906. The scale, named Control of thoughts is therefore composed of 11 items (2, 5, 12, 15, 17, 29, 37, 44, 54, 59, 69).

Responsibility for omission: Items which load highly onto such factor come from the responsibility scale (n=5) and 3 items each from overestimation of threat and importance of thoughts. The model does not satisfy the minimum criteria of acceptability. Items 82, 72, 76, 34 and 66 were therefore eliminated. The factor was reconceptualized as a different type of responsibility, different from factor two in that it refers to a concept of prevention or omission, rather than harm through errors of commission. For theoretical reasons, items 20 ("If I have the opportunity then I must do something to prevent misfortunes from happening") and 23 ("I should try and prevent, at any cost, even the most improbable misfortunes") were added to this scale, even though they were excluded from factor II because they did not meet the CFA criteria. The final scale is composed of 7 items, all coming from the responsibility scale (7, 20, 23, 38, 41, 77, 81). In contrast with factor 2, defined as responsibility for errors of commission, this factor seems to refer to a type of responsibility by omission. The model demonstrates good indices of goodness-of-fit: RMSEA=0.065; GFI=0.979; AGFI=0.958; CFI=0.960.

Lastly, factor six corresponds to the domain defined as importance of thought. It's loaded by 7 items originally from scale importance of thought (14, 24, 34, 46, 55, 58, 83), which corresponds to the construct defined as Thought-Action Fusion (TAF; Shafran, 1996). The model has satisfactory indices of goodness-of-fit: RMSEA=0.0803; GFI=0.967; AGFI=0.934; CFI=0.900.

The final version of the Italian OBQ (OBQ-Italian 46 ; OBQ-I46) is therefore composed of 46 items divided into five factors.

PSYCHOMETRIC CHARACTERISTICS OF THE OBQ-I46

Internal Consistency and Test-Retest Reliability

Internal consistency was evaluated using Cronbach's alphas. Generally values with the range from .7-.9 are considered to be very good, even if values around .6 are still acceptable (e.g., Bergstrom et al., 1998). Test-retest reliability on a subsample of 102 subjects was evaluated using a Pearson's correlational test. Table 3 reports the reliability coefficients for the five scales of the OBQ-I46.

Table 3. Number of items, Internal consistency , test-retest reliability of the OBQ subscales

	Item	α di Cronbach	Test-retest
OBQ			
Perfectionism	11	.86	.84
Responsibility for harm	10	.80	.73
Control of Thoughts	11	.82	.67
Responsibility of omission	7	.65	.67
Importance of Thoughts (TAF)	7	.68	.77

In general, internal consistency seems satisfactory at least for four of the five scales with values varying from .68 ("Importance of thoughts") to .86 ("Perfectionism"). The Responsibility by omission scale has slightly lower internal consistency, although still at an acceptable level. As far as Perfectionism is concerned , the weakest item is item 11 ("There is only one way to do things correctly"), the exclusion of which would increase the value to .87. In Responsibility for harm scale the elimination of item 4 ("If I imagine something bad is going to happen then it is my responsibility to make sure it doesn't actually happen") would increase the coefficient to .81. In Control of Thought scale, the elimination of item 2 ("Having control over your thoughts is a sign of good character") would increase the coefficient to .82. In Responsibility of omission scale the weakest item is 20 ("If I can I must do something to prevent misfortunes from happening"), the exclusion of which would lead to a coefficient of .68. The temporal stability is good, if not very good, (range .67-.84), taking into consideration the fairly large time interval between testing points.

INTERCORRELATION BETWEEN THE SCALES

In order to evaluate the level of differentiation between, or independence of, the constructs measured by the OBQ-I46, a matrix correlation was calculated and analyzed using

the sample of students ($n=752$). Table 4 displays the pattern of association that is moderately high, varying from .39 to .66. Analysing the correlations individually, moderate correlations can be seen between the two scales measuring the two types of responsibility (harm and omission, $r=.65$) and between the scales Control of thoughts and Importance of thoughts ($r=.58$).

Table 4. Intercorrelations between OBQ scales

	Perfectionism	Responsibility for harm	Control of Thought	Responsibility of omission
OBQ				
Perfectionism	-			
Responsibility for harm	.54	-		
Control of thoughts	.50	.54	-	
Responsibility of omission	.43	.65	.53	-
Importance of thoughts	.39	.44	.58	.48

All correlations are significant at $p<.001$.

CRITERION-ORIENTED VALIDITY

We compared a sample of students with “highly obsessive tendencies” with a sample defined as having “low obsessive tendencies”. Students were divided into the two groups on the basis of the Padua Inventory.

Table 5. Comparison Between Subjects Defined With High Obsessive Tendencies vs Low Obsessive Ones On The Basis of Padua Inventory Score

	Low OCD tendency N=158 M±SD	High OCD tendency N=166 M±SD	F	p
OBQ				
Perfectionism	22.8±8.1	38.3±12.4	174.19	0.0001
Responsibility for harm	28.8±9.7	42.0±9.2	156.2	0.0001
Control of thoughts	23.4±8.5	35.1±11.2	110.45	0.0001
Responsibility of omission	14.5±4.6	19.6±5.7	77.37	0.0001
Importance of thoughts	11.1±4.6	16.1±6.1	68.001	0.0001
BAI	4.8±4.03	16.3±9.2	206.15	0.0001
BDI	3.1±3.5	14.6±10.2	178.19	0.0001

Those with scores above the 75th percentile were placed in the former group and those with scores under the 25th percentile in the latter. The first group was composed of 158 subjects, with mean age= 21.1±1.56 (range 17-37), females=88 (55.7%) vs males=70 (44.3%). The group with the PI score higher than the 75th percentile was composed of 166 subjects, with mean age=20.7±1.65 (range 18-27), females=108 (65.1%) vs males=58 (34.9%). It is worth noting the different proportions of male and female students in each of the groups, with a prevalence of females in the second group ($\chi^2=2.97$, $p<.05$), in line with data from the literature. Moreover, students with high OCD tendencies obtained higher scores to measures of general anxiety and depression (BAI and BDI).

In Table 5 the means and standard deviations on the OBQ-I46 scales across the groups are reported. A one-way analysis of variance was completed with group as the independent variable (low vs high). The subjects with “high obsessive tendencies” obtained scores significantly higher on all scales of the OBQ-I46 with respect to subjects with “low tendencies”.

CONVERGENT AND DIVERGENT VALIDITY

The convergent validity was evaluated considering the correlations between the scales of the OBQ-I46 and the scales and total scores of the PI. Furthermore, correlations between OBQ-I46, the BAI and the BDI were calculated. Table 6 shows the pattern of correlations, all at significance levels of $p<.001$.

The cognitive domain most highly correlated with the OCD symptoms was Perfectionism, with r varying between .51 (PI1: impaired control over mental activities) and .32 (PI4: urges and worries of losing control over motor behaviors), while the scale with lower, yet still significant, correlations is the Importance of thoughts with r varying between .34. (PI1) and .17 (PI4). Generally, the scales of the OBQ-I46 correlate acceptably (between .32 and .51) with the PI total score, while the values of the lowest correlations are with scale 4, which, in effect, measures impulses, a dimension which is not especially representative of the OBQ (range between .32 and .17).

Table 6. Convergent validity: correlations of the obq scales with the padua inventory

	PI1	PI2	PI3	PI4	PI Total
OBQ					
Perfectionism	.51	.36	.36	.32	.51
Responsibility for harm	.44	.34	.35	.23	.45
Control of thoughts	.44	.28	.33	.25	.43
Responsibility of omission	.35	.22	.26	.23	.35
Importance of thoughts	.34	.20	.26	.17	.32

The correlations are significant at $p<.001$.

PI1=impaired control over mental activities; PI2=becoming contaminated; PI3=checking behaviors; PI4=urges and worries of losing control over motor behaviors.

Since, both theoretically and statistically, the influence of measures of psychological distress (anxiety and depression) on measures of OCD symptoms has been demonstrated, partial correlations were calculated in order to control for the effects of BAI e BDI. Table 7 displays the correlations of the OBQ-I46 scales with PI, once the effect of anxiety and depression, as measured by BAI and BDI, has been removed. Almost all of the correlations remain significant, even if, as expected, their strength is reduced. Overall, the indices of r s for all of the scales are lowered. Specifically, while all of the OBQ-I46 scales continue to correlate significantly with the total score of the Padua Inventory (between .23 a .37), correlations with scale 4 (urges and worries of losing control over motor behaviors) are lower – some of them reaching non-significance.

Table 7. Convergent validity: partial correlation of the OBQ scale with Padua Inventory

	PI1	PI2	PI3	PI4	PI Total
OBQ					
Perfectionism	.37**	.26**	.26**	.11*	.37**
Responsibility for harm	.35**	.27**	.28**	.09*	.37**
	PI1	PI2	PI3	PI4	PI Total
Control of thoughts	.36**	.20**	.26**	.12*	.34**
Responsibility of omission	.33**	.18**	.21**	.16**	.32**
Importance of thoughts	.25**	.12**	.19**	.04§	.23**

* $p < .01$, ** $p < .001$, §=Not Significant.

PI1=impaired control over mental activities; PI2=becoming contaminated; PI3=checking behaviors; PI4=urges and worries of losing control over motor behaviors.

Regression Analysis

This procedure was employed in order to verify the capacity of the cognitive measure to predict specific OCD symptoms after emotional distress variables had been controlled for. Given the nature of the dependent variable a linear regression was calculated. With the aim of controlling for the effect of the variables of depression and anxiety, the variables were entered into the model in blocks, first with the insertion of the BAI and BDI scores, and secondly all scores from the OBQ-I46 scales were entered simultaneously.

In the first regression analysis the total score of the PI, representing many symptomatic manifestations of OCD, was used as the dependent variable. The BAI and BDI scores were inserted into the first block, followed by the OBQ scales in the second. The R^2 of the resultant model was .52. Table 8 displays the beta values and the associated levels of significance for each of the variables entered into the model.

The results suggest that the cognitive variables, with the exception of scales Responsibility of omission and Importance of thought, predict additional variance of the obsessive symptomology, over and above that explained by anxiety and depression.

A second series of analyses evaluated the power of Perfectionism, Responsibility for harm, and Control of thoughts to predict the scores of single PI scales in order to verify whether there was a relationship between the various cognitive domains and specific OCD symptom clusters. The three scales individually predicted different OCD symptoms (i.e., the different PI subscales), with the exception of scale 4 of Padua Inventory (Urges and worries of losing control over motor behaviors) at a significant level. Interestingly, Responsibility for omission positively and significantly predicts scale 4 of the PI.

Table 8. Output of linear regression analysis using as dependent variable Padua Inventory total score

		β	Sig.	R ²
Block 1	BAI	.92	.0001	
	BDI	.74	.0001	.39
		β	Sig.	R ²
	OBQ			
Block 2	Perfectionism	.38	.0001	
	Responsibility for harm	.31	.001	
	Control of thoughts	.26	.003	
	Responsibility of omission	.24	NS	
	Importance of thoughts	-.04	NS	.52

Normative Values and Gender Differences

Table 9 reports the mean scores and the standard deviations of the various scales of the OBQ-I46. Significant differences emerge between males and females in Control of thoughts and Responsibility of omission.

Table 9. Norms divided by gender

OBQ	Males	Females	F	p
Perfectionism	30.1±11.5	30.6±11.9	.30	NS
Responsibility or harm	36.1±10.8	35.7±10.4	.18	NS
Control of thoughts	31.2±11.3	28.5±10.2	11.45	.001
Responsibility of omission	18.3±5.7	16.7±5.3	16.4	.0001
Importance of thoughts	13.4±5.7	14.1±5.5	2.69	NS

DISCUSSION AND CONCLUSIONS

The main aim of this study was to verify the psychometric properties of the Italian version of the Obsessive Beliefs Questionnaire. A first attempt was made in order to verify the goodness-of-fit of the three-factor model proposed by the recent revision made by the

OCCWG group, without appreciable results. An explorative factor analysis was then therefore completed. It revealed six factors: perfectionism, responsibility for harm, overestimation of danger, control of thoughts, responsibility for omission, importance of thoughts. Several differences emerged in contrast with the original American 87-item version: the absence of the intolerance of uncertainty, divided between perfectionism and control of thoughts; the subdivision of the responsibility scale into the scales responsibility for harm and responsibility for omission.

Lastly, the confirmatory factorial analysis reduced the number of factors and as well as the number of items/scales. The Italian version of the Obsessive Beliefs Questionnaire is therefore composed of 46 items, divided into five scales.

Scale 1 corresponds to the domain of Perfectionism, and is composed of 11 items all originally belonging to the Perfectionism scale of the OBQ87. Analyzing the content of the items, the scale measures that type of perfectionism linked to the need to always do things perfectly, and to perceived failure when high standards are not met.

Scale 2, defined as Responsibility for harm, is composed of 10 items which measure that sense of responsibility that is felt when an action is deemed to be immoral or harmful. Seven items out ten pertained to the original scale of responsibility from the OBQ87, while of the three remaining items two belonged to the overestimation of danger scale and one to the intolerance of uncertainty scale. Analyzing the content, the scale measures the degree of conviction relative to perceived responsibility for facts or actions taken. In concert with the theme, even items that come from other scales seem to relate, albeit indirectly, to the same concepts (e.g. item 68: “even when I’m careful I sometimes think that I could cause or suffer a bad event”).

Scale 3, defined as Control of thoughts, is composed of 11 items all originally from the Control of thoughts scale. The content of the items is linked to the need to have complete control over thoughts and over the consequences, both emotional and concrete, of failures and shortcomings.

Scale 4, defined as Responsibility for omission, is composed of 7 items originally belonging to the responsibility scale, with the exception of item 50 (overestimation of threat). Through analysis of the content of the items it emerges that this dimension concerns a type of excessive responsibility that is most concerned with prevention of harm or harm by omission.

Lastly, scale 5, defined as Importance of thoughts, is composed of 7 items all originally from the Importance of thoughts scale. The scale measures the strength of the conviction that having a thought in itself means that it is important, the idea of thought-action equivalency is well illustrated in the concept of “Thought-action fusion”.

The reliability of these dimensions was evaluated using Cronbach’s alpha test of internal consistency and Pearson’s formula of temporal stability. In accordance with the convention that a Cronbach alpha of $\geq .70$ is seen as acceptable and values equal to $\geq .80$ are considered good, the internal consistency of the Italian version of the OBQ can be judged to be largely acceptable for the scales measuring Responsibility for omission and Importance of thoughts, and good for the other subscales (Control of thoughts, Responsibility for harm and Perfectionism). The scales also demonstrated a good or very good level of temporal stability. Lastly, the five domains correlated each other at a relatively high degree.

In summary, we have seen that three dimensions of the Italian version of the OBQ mirror the original constructs identified by the OCCWG (perfectionism, need for thought control and importance attributed to thoughts), and another one is expressed in two different elements

(responsibility for omission and for harm). Two original dimensions of the OBQ are eliminated (overestimation of threat and intolerance of uncertainty) from Italian version.

Looking at the two constructs of responsibility, the literature demonstrates that, generally, common sense attributes a more negative meaning to decisions which require an action, even when confronted with options which results in the same negative consequences. This phenomenon, which has been called the omission bias, was fully described by Spranca (1991). Generally, imagining possible, negative, hypothetical situations, people are more inclined to feel greater regret if they have completed an action, than if they have not acted. Spranca et al. (1991) found that actions were viewed more positively than inaction when either led to positive consequences, in contrast, when the consequences were negative it was the action that was viewed more negatively than the failure to act. Kordes-de Vaal (1996) found similar results in a replication which extended Spranca's experimental paradigm, subjecting four groups to scenarios representative of situations in which the possible negative outcome could be linked to an action (the subject deliberately chooses to do harm to another) or inaction (the subject, while possessing information necessary to avoid a disasters, chooses not to). The results showed a significant difference in the level of perceived causality in personal terms. The studies of Spranca and others, in sum, suggest a different attitude, even in terms of morality and immorality, regarding the consequences of action and inaction, which is a result of various factors: the physical movement connected to action and its inevitable absence in inaction, the presence of salient, alternative causes in the case of inaction, as well as the idea that the consequences of inaction would be similar even if the agent was not present or ignored the effects of inaction. The conclusion of these studies therefore appears clear: people are more inclined to consider themselves responsible for consequences when they are linked to an actual action, rather than to inaction, even when the consequences are effectively the same. This therefore justifies the presence of different measures of responsibility.

It is important to note that the presence of various measures of responsibility might depend also on the fact that our sample does not present problems of a psychopathological nature. Indeed, Wroe e Salkovskis (2000) presented various different scenarios to an OCD group, an anxious non-OCD group and a non-clinical group, asking each for a self-evaluation concerning responsibility, morality and perceived distress. The results revealed significant differences between the OCD group and the other two groups: the OCD group did not show the bias of omission. The explanation lies, according to the authors, in the peculiarity of obsessive thought patterns and the assumption of responsibility which is typical of the disorder. Because of these characteristics, the obsessive individual even "interprets" inaction in terms of choice and, therefore, feels equally responsible as in the case of an actual action. Actually, also in the current study the Responsibility for omission scale predicted symptoms (Urges and worries of losing control over motor behaviors) not so typical of clinical OCD: such dimension could not be as useful as others when used with clinical population.

In any case, to our knowledge, this subdivision of the concept of responsibility for actions and inaction, which emerged from the factor analysis of the OBQ, is only present in the Italian context. Whether this is due to cross-cultural factors or to the type of sample studied constitutes an interesting avenue for future research.

The two theoretical domains that were not found in this study have, in some way, peculiar characteristics. The first (overestimation of threat) is extremely generic and, it could be hypothesized, is more connected to one's value system. For instance, Sica, Novara and

Sanavio (2002_(b)) evaluated superstitious and non-superstitious individuals on the original OBQ and well-established measures of obsessive-compulsive symptoms, depression, anxiety and worry. After controlling for anxiety and depression, highly superstitious subjects scored higher than subjects low in superstition on the OBQ domain of overestimation of threat. An alternative explanation sees general perceptions of threat being linked to any state of anxiety (“the world is full of danger”). Even in the three-factor American version, this dimension loses importance in favour of the concept of responsibility. Lastly, also in another Italian study the overestimation of danger did not discriminate between OCD patients and patients with generalized anxiety disorder (Sica et al., 2004).

The intolerance for uncertainty scale, on the other hand, was originally composed of two sets of items: those dealing with a sense of vulnerability (e.g., “I often think that I will be overwhelmed by unforeseen events”) and those concerned with the need of certainty (e.g., “I must be certain of my decisions”; OCCWG, 1997). Such ambiguity is confirmed by the fact that, in normal and anxious individuals, the internal consistency of this scale is not sufficient (Sica et al., 2004). Furthermore, as we have seen, the OCD population does not obtain scores that are significantly higher than those of anxious patients on the Perfectionism/Certainty scale of the OBQ-44. There are, therefore, three possibilities for this scale: 1) the domain is conceptual ambiguous; 2) the domain has not been adequately measured (i.e., the items do not adequately represent the concept); 3) the domain is only detectable in patients.

All dimensions of the OBQ-I46 discriminate individuals with OCD tendencies from those who did not report this feature. Moreover, all dimensions were significantly associated with OCD symptoms also when general distress (i.e., anxiety and depression) was controlled. On the other hand, other results questioned the specificity of such dimensions (a core theoretical point of cognitive theory of OCD). First, all the five scales correlated in a similar way with various symptoms of OCD (i.e., the different scales of Padua Inventory). Bearing in mind also the relatively high degree of overlap among the different dimensions, it may mean that the OBQ-I46 is not able to predict specific symptoms pattern, a strong limitations considering the heterogeneity of OCD manifestation. Second, only three dimensions (Perfectionism, Responsibility for harm and Control thoughts) resulted good predictors of OCD symptoms in a linear regression model, whereas Responsibility of omission and Importance of thoughts did not predict OCD symptoms at all.

Interestingly, perfectionism and control of thoughts were among the best predictors of OCD symptoms in a recent study carried out across three cultures (Sica, Taylor, Arrindell & Sanavio, 2006). Moreover, as mentioned before, a study completed on Italian patients showed that perfectionism and control of thoughts were two of the three cognitive domains which better discriminated patients with obsessive-compulsive disorder from patients with generalized anxiety disorder and non-clinical individuals (Sica et al., 2004). Another study has stressed the specificity of the control of thoughts domain. In an investigation carried out in Spain, 31 OCD patients, 22 depressed patients, 31 non-obsessive anxious patients, and 30 non-clinical community subjects were compared on the Obsessional Intrusions Inventory-Revised (ROI; Purdon & Clark, 1994), a measure containing six scales measuring OCD-dysfunctional beliefs similar to those measured by the OBQ. Between-group differences indicated that two dysfunctional appraisals (worrying that the thought will come true, and the importance of controlling thoughts) were specific to OCD patients. (Morillo, Belloch & Soriano, 2007).

Additional studies are therefore warranted to ascertain whether perfectionism and control of thoughts are more important and specific than other cognitive domains in predicting OCD symptoms.

The domain of importance of thoughts may be culture-specific, instead. For instance, a study comparing individuals with differing degrees of religious involvement showed that the importance of thoughts belief was linked to OCD symptoms in individuals with a substantial degree of religiosity (Sica, Novara & Sanavio, 2002_(a)). Lastly, importance of thought may be relevant for a subgroup of individuals of clinical interest with overvalued ideation, a well known feature of some OCD individuals (Neziroglu & Stevens, 2002).

From a methodological point of view it should be emphasized that further information on the usefulness of the OBQ, in theoretical, clinical and psychotherapeutic terms, can only come from studies of the clinical population, which have as their aim the verification of the specificity of the constructs in the OCD population. Indeed, we do not know whether the data obtained in this study would be replicated if the questionnaire had been administered to a clinical population. On the other hand, studies conducted by various independent research groups have obtained results which are partly convergent with those which we have presented.

Finally, two last theoretical considerations appear to be important. First, as we mention before, recent research on OCD underscores the considerable heterogeneity of this disorder. For example, in their review, McKay and colleagues (2004) have identified as many as nine subtypes or replicable dimensions of OCD: contamination/washing, harming/checking, hoarding, symmetry/ordering, obsessions, sexual and religious, certainty, sexual-somatic, and contamination/harming. Studies on OCD heterogeneity, among other things, therefore suggests that OCD subtypes may differentially relate to cognitive features (e.g., Tolin, Woods & Abramowitz, 2003), an issue that warrants more study. Second, the cognitive theory of OCD postulates that beliefs are *causally* related to OCD symptoms. However, as has emerged in research of other emotional disorders (e.g., Segal, Williams & Teasdale, 2002), beliefs and schema may be also *consequences* of psychopathology. Several studies are under way to ascertain such a possibility.

REFERENCES

- Beck A.T. & Steer, R.A. (1990). *Beck Anxiety Inventory Manual*. San Antonio, TX: Psychological Corporation.
- Beck, A. T., Epstein, N., Brown, G., & Steer R. A. (1988). An inventory for measuring clinical anxiety: Psychometric properties. *Journal of Consulting and Clinical Psychology*, 56, 893-897.
- Beck, A.T. & Steer, R.A. (1987). *Manual for the revised Beck Depression Inventory*. San Antonio, TX: Psychological Corporation.
- Beck, A.T. (1976). *Cognitive therapy and the emotional disorders*. New York: International Universities Press.
- Beck, A.T., Emery, G. & Greenberg, R.L. (1985). *Anxiety disorders and phobias: a cognitive perspective*. New York Basic Books.

- Beck, A.T., Freeman, A. & Emery, G. (1990). *Cognitive therapy of personality disorders*. New York: Guilford.
- Beck, A.T., Rush, A.J., Shaw, B.F. & Emery, G. (1979). *Cognitive therapy of depression*. New York: Guilford.
- Beckstead, J.W. (2002). Confirmatory factor analysis of the Maslach Burnout Inventory among Florida nurses. *International Journal of Nursing Studies*, 39, 785-792.
- Bergstrom, G., Jensen, I.B., Bodin, L., Linton, S.J., Nygren, A.L. & Carlsson, S.G. (1998). Reliability and factor structure of the Multidimensional Pain Inventory. *Pain*, 75, 101-110
- Borwne, M.W. & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J.S. Long (eds.), *Testing Structural Equation Models*, (136-162). Newbury Park: Sage Publications.
- Burns, G. L., Formea, G. M., Keortge, S., & Sternberger, L. G. (1995). The utilization of non-patient samples in study of obsessive-compulsive disorder. *Behavior Research and Therapy*, 33, 133-144.
- Careau, Y., O'Connor, K., Turgeon, L., & Freeston, M. (2003, March). Childhood experiences and adult beliefs associated with OCD. *Poster session presented at the 23rd Annual conference of the Anxiety Disorder Association of America*, Toronto, Canada.
- Cattell, R.B. (1966). The scree test for the number of factors. *Multivariate Behavioral Research*, 1, 245-276.
- Centomo, C. & Sanavio, E. (1992). Padua Inventory e Beck Depression Inventory: indagine su studenti di scuola media superiore. *Manuscript not published*.
- De Vellis, R. F. (1991). *Scale development: Theory and applications*. Newbury Park, CA: Sage.
- Ebel, R. L. and Frisbie, D. A. (1991). *Essentials of educational measurement*. (5th ed.). Englewood Cliffs, NJ: Prentice-Hall.
- Gibbs, N. A. (1996). Nonclinical populations in research on obsessive-compulsive disorder: A critical review. *Clinical Psychology Review*, 16, 729-773.
- Haynes, S. N., Richard, D. C. S. and Kubany, E. S. (1995). Content validity in psychological assessment: A functional approach to concepts and methods. *Psychological Assessment*, 7, 238-247.
- Hu, L.T. & Bentler, P.M. (1999). Cutoff criteria for fit indices in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling*, 6, 1-55
- Joreskog, K.G. & Sorbom, D. (1996). *LISREL 8: User's Reference Guide*. Scientific Software International Inc. Chicago.
- Kinzie, J. D., and Manson, S. M. (1987). The use of self-rating scales in cross-cultural psychiatry. *Hospital and Community Psychiatry*, 38, 190-196.
- Kordes de Vaal, J. (1996). Intention and the omission bias: Omissions perceived as nondecisions. *Acta Psychologica*, 93, 161-172.
- McKay, D., Abramowitz, J. S., Calamari, J. E., Kyrios, M., Radosky, A., Sookman, D., Taylor, S., & Wilhelm, S. (2004). A critical evaluation of obsessive-compulsive disorder subtypes: Symptoms versus mechanisms. *Clinical Psychology Review*, 24, 283-313.
- Morillo, C., Belloch, A., & Garcia-Soriano, G. (2007). Clinical obsessions in obsessive-compulsive patients and obsession-relevant intrusive thoughts in non-clinical, depressed

- and anxious subjects: Where are the differences? *Behaviour Research and Therapy*, 45, 1319-1333.
- Neziroglu, F. & Stevens, K. P. (2002). Insight: Its conceptualization and assessment. In R. O. Frost & G. Steketee (Eds.), *Cognitive approaches to obsessions and Compulsions: Theory, assessment and treatment* (pp. 203-214). Oxford: Elsevier Press.
- Obsessive Compulsive Cognitions Working Group (1997). Cognitive assessment of obsessive-compulsive disorder. *Behavior Research and Therapy*, 35, 667-681.
- Obsessive Compulsive Cognitions Working Group (2001). Development and initial validation of the obsessive belief questionnaire and the interpretation of intrusion inventory. *Behavior Research and Therapy*, 39, 987-1006.
- Obsessive Compulsive Cognitions Working Group (2003). Psychometric validation of the obsessive belief questionnaire and interpretation of intrusion inventory. Part I. *Behavior Research and Therapy*, 41, 863-878.
- Obsessive Compulsive Cognitions Working Group (2005). Psychometric validation of the obsessive belief questionnaire and interpretation of intrusion inventory. Part II. *Behavior Research and Therapy*, 43, 1527-1542.
- Purdon, C., & Clark, D. (1994). Obsessive Intrusive thoughts in nonclinical subjects. Part II. Cognitive appraisal, emotional response and thought control strategies. *Behaviour Research and Therapy*, 32, 403-410.
- Salkovskis, P. M. & Harrison, J. (1984). Abnormal and normal obsessions - a replication. *Behaviour Research and Therapy*, 22, 549-552.
- Sanavio, E. (1988). Obsession and compulsion: The Padua Inventory. *Behaviour Research and Therapy*, 26, 169-177.
- Segal, Z. V., Williams, J. M. G. & Teasdale, J. D. (2002). *Mindfulness-based cognitive therapy for depression*. New York: Guilford.
- Shafran, R., Thordarson, D. & Rachman, S. (1996). Thought action fusion in obsessive compulsive disorder. *Journal of Anxiety Disorders*, 10, 379-391.
- Sica, C. & Ghisi, M. (2007). The Italian Versions of the Beck Anxiety Inventory and the Beck Depression Inventory-II: Psychometric Properties and Discriminant Power. In: M. A. Lange (Ed.), *Leading-Edge Psychological Tests and Testing*, (pp. 27-50). Nova Science Publishers.
- Sica, C., Coradeschi, D., Sanavio, E., Dorz, S., Manchisi, D., & Novara, C. (2004). A study of the psychometric properties of the Obsessive Beliefs Inventory and Interpretations of Intrusions Inventory on clinical Italian individuals. *Journal of Anxiety Disorders*, 18, 291-307.
- Sica, C., Novara, C., Sanavio, E. (2002_a). Religiousness and Obsessive-Compulsive Cognitions and Symptoms in an Italian Population. *Behaviour Research and Therapy*, 40, 813-823.
- Sica, C., Novara, C., Sanavio, E. (2002_b). Culture and psychopathology: Superstition and obsessive-compulsive cognitions and symptoms in a non-clinical Italian sample. *Personality and Individual Differences*, 32, 1001-1012.
- Sica, C., Taylor, S., Arrindell, W. A. & Sanavio, E. (2006). A cross-Cultural test of the cognitive theory of obsessions and compulsions: A comparison of Greek, Italian, and American individuals. A preliminary study. *Cognitive Therapy and Research*, 30, 585-597.

-
- Spranca, M., Minsk, E. & Baron J. (1991). Omission and commission in judgment and choice. *Journal of Experimental Social Psychology*, 27(1) 76-105.
- Sterneberger, L., & Burns, G. (1990). Obsessive compulsive disorder: symptoms and diagnosis in a college sample. *Behavior Therapy*, 22, 569–576.
- Tabachnick, B.G. & Fidell, L.S. (1996). *Using multivariate statistics (3ed)*. New York: Harper Collins.
- Tolin, D. F., Woods, C. M., & Abramowitz, J. S. (2003). Relationships between obsessive beliefs and obsessive-compulsive symptoms. *Cognitive Therapy and Research*, 27, 657-669.
- Wroe, A.L. & Salkovskis, P.M. (2000). Causing harm and allowing harm: A study of beliefs in obsessional problems. *Behaviour Research and Therapy*, 38(12), 1141-1162.

Reviewed by Corrado Caudek, Professor of Quantitative Methodology, Department of Psychology, University of Firenze, Italy

Chapter 13

HAPTIC ABILITIES IN INFANCY AND THEIR RELATION TO VISION: A REVIEW

Arlette Streri¹

Université Paris Descartes, France

ABSTRACT

The old debate concerning the primitive unity (nativist conception) or the separation (empiricist conception) of senses at birth has been revived in recent years, as difficulties in the methodology of studying perception in babies were overcome. How can babies know by touch? To answer to this question, three aspects of human infants' haptic abilities are presented in this review. How the young babies: 1. Perceive information and form a perceptual representation of objects derived from the hands alone; 2. Transfer this information to vision in an intermodal process; 3. Obtain haptic knowledge in limited exploration conditions as they do in the visual modality?

Using a habituation/dishabituation procedure, experiments have revealed that infants, from birth, are able to discriminate object shapes in the manual as well as in the visual mode. These abilities are a prerequisite for understanding the relations between the haptic and the visual sensory modalities in cross-modal transfer tasks. Using an intersensory successive preference procedure, several experiments provided evidence for cross-modal recognition from touch to vision from birth. The links however are limited, partial and not reciprocal. Nevertheless, adaptations of paradigms for studying visual cognition reveal that the haptic system shares some amodal mechanisms with the visual modality. Despite various discrepancies between both modalities, conceiving the world is possible with the hands as well as the eyes soon after birth.

Keywords: haptic perception, haptic cognition, cross-modal transfer, vision, infancy

¹ Address for correspondence: Arlette Streri, "Laboratory for Psychology of Perception" UMR. 8158, centre Biomédical des Saints-Pères - 45, rue des Sts Pères 75270 Paris cedex 06 France Email: arlette.streri@parisdescartes.fr

INTRODUCTION

In recent years, there has been an increased interest in the development of haptic exploration in animals and human beings (see Hatwell, Streri, and Gentaz, 2003). In the haptic modality, the mouth and the hands are the best organs for perceiving and knowing the properties of the surroundings. In many mammals, the mouth and the vibrissal system are the most sensitive body parts and the main tools of perceptive exploration. In rodents, for example, the perception of the environment relies mainly on the vibrissae (Carvell and Simons, 1990). In nonhuman primates, the mouth, rich in tactile receptors, remains privileged for sniffing, mouthing, etc. but the differentiation of the anterior limbs into prehensile extremities allows considerable broadening of exploratory abilities. For nonhuman primates, the hands are also an important tool used for feeding, running, stroking, active manipulation, etc. permitting them to vary their activity in relevant ways (Tomasello, 1998).

However, such specialization culminates in human beings. Bipedalism has freed the hands and arms from locomotion, creating increased opportunity for manual expression (Corballis, 2003). Hands and arms have become a principal tool of investigation, manipulation and transformation of the world. The importance of manual activities in human beings has been approached through anthropological studies, which have established a causal link between the development of human intelligence and the conquest of bipedal walking and the subsequent freeing of the hands. Once the hands became free, tools could be created, causing an increase of brain capabilities. As a consequence, in the research about the evolution of our species, brain and hands are always closely linked (see Corballis, 2003, for a discussion). Moreover, although not universally accepted, researchers have also suggested that in our species, articulate language emerged from manual gestures (Armstrong, 1999; Corballis, 2002; Rizzolatti and Arbib, 1998). There are also a number of suggestions that the left-lateralization of right-handedness and speech dominance in the left-side of the cerebral cortex are causally related in the evolution of our species, although there is disagreement as to the direction of the causality. Another hypothesis would be that the two processes might have evolved independently (see Corballis, 2003, for a discussion).

RESEARCH IN INFANCY: A GAP BETWEEN THE VISUAL AND HAPTIC MODALITIES

Despite the importance of the role of hands in human intellectual development, several decades of research in infancy have been devoted mainly to the visual mode (see Clifton, 2001, for a historic review). Numerous studies have brought a wealth of evidence for perceptual and cognitive competencies in very young infants (Kellman and Arterberry, 1998). There is clear evidence that size and shape constancies are present at birth (Slater and Morison, 1985; Slater, Mattock and Brown, 1990). Neonates are sensitive to complex stimuli such as face-like patterns (Goren, Sarty and Wu, 1975) and look preferentially at faces that are judged attractive by adults (Slater, Quinn, Hayes and Brown, 2000). Young infants are able to understand complex visual events and can reason about physical laws that constrain objects' movements in space and time. They are sensitive to strange or impossible events that contravene these laws (see Spelke, 2003, for a review). For example, two and a half month-

old infants understand that an object exists even if it is hidden behind another object or a screen and that an object cannot occupy the same place as another object or go through it (see Baillargeon, 1995; Spelke, Breinlinger, Macomber, Jacobson, 1992). Despite this knowledge concerning the development of visual perception, much less is known about comparable issues for haptic processes. Is it possible to show similar competencies in the haptic modality, particularly in the manual mode?

MAIN REASONS OF THIS GAP

Basic characteristics of the haptic system stem from the fact that the hands are both perceptual systems able to explore and recognize the surface of objects and their properties and motor organs performing daily actions controlled by tactile-kinesthetic reafferences (see Hawell, 1994; Loomis and Lederman, 1986). Wealth of research has been devoted to the description and development of manual skills in infancy and children, because manual skills are specific to the haptic system.

They give it a unique and original property among the senses. In contrast, few studies have focused on the emergence and development of haptic perception and cognition in very young infants. The main reason is that, for a very long time, newborns and older infants have been described as displaying many reflex reactions and clumsy arm movements. Particularly, newborns' hands are often described as closed or exhibiting either grasping or avoiding reflexes, which are inappropriate behaviors for holding an object and gathering and processing information (Twitchell, 1965).

Another reason for the paucity of research in this area is that young infants spontaneously display numerous behaviors with their mouth but not with their hands. Numerous studies of neonatal imitation of tongue protrusion or mouth opening (Meltzoff and Moore, 1977), coordination of hand-mouth actions (Butterworth and Hopkins, 1988), etc. reveal early developing competencies and skills of young babies' mouths. Given these data, the mouth has been considered by researchers as an exploratory tool and an important part of the haptic system, playing a major role in an infant's gathering of information about objects.

Consequently, the manual system of the haptic modality was neglected and almost forgotten. For example, to provide evidence of cross-modal transfer from mouth to eyes in one month-old infants, Meltzoff and Borton (1979) wrote in their paper published in *Nature*, "As infants of this age (26 to 33 days) will not explore objects manually, the tactual stimuli were constructed by modifying pacifiers so that small, hard rubber shapes could be mounted on them..." p. 403.

This argument was taken up by Gibson and Walker (1984) in the same cross-modal transfer task at the same age. They wrote, "Since manual exploration was out of the question, oral exploration provided the haptic experience for familiarization" p. 457. Thus, numerous researchers thought that manual exploration was very limited in infancy (see Rochat, 1989). It is very likely that, from birth, mouthing and oral exploration are fundamental means for infants to interact with objects. But, these interactions are often aided by the hands and not directly taken up by the mouth.

OVERVIEW

Our research has focused mainly on the role of the hands as perceptual systems considered in isolation. This paper addresses first the question of abilities of infants to perceive object properties by the hands considered in isolation, i.e. without visual control. These abilities are a prerequisite for understanding the relations between the haptic mode and the visual mode. Considering that several studies provided evidence of early lateralization and handednesses in infancy (Caplan and Kinsbourne, 1976; Petrie and Peters, 1980; Hawn and Harris, 1983), in our experiments, infants were often stimulated both with the left and the right hand. Next, the paper considers two kinds of relation between vision and touch: cross-modal transfer of shape between the sensory modalities and haptic cognition in comparison to visual cognition. Finally, we suggest that our results from normal infants can shed light on research from children with autistic spectrum disorder as well as work with children with visual impairment or blindness.

1. PERCEPTION OF THE SHAPE OF OBJECTS

Some Considerations in Human Adults

Touch is a perceptual system that depends on contact with surfaces and on the quality of proximal reception. However, the tactual perceptual field is limited to the zone of contact with the object and has the exact dimensions of the surface of the skin in contact with the stimulus. In a passive touch condition, parallel processing and spatial discrimination abilities through the skin are nevertheless possible by way of a vibratory stimuli transmission system (Geldard and Sherrick, 1965). However, to comprehend the whole object and obtain a good representation of it, voluntary movements must be made to compensate for the smallness of the tactile perceptual field. The kinaesthetic perceptions resulting from these movements are necessarily linked to the purely cutaneous perceptions generated by skin contact, and they form a whole called “haptic” (or tactilo-kinaesthetic, or active touch) perception. As a result, object perception in the haptic mode is highly sequential. This property increases the load on working memory and requires a mental reconstruction and synthesis to obtain a unified representation of a given object (Revesz, 1950).

In adults, the hands alone are able to gather information about the different properties of objects. But these properties do not have the same salience under haptic exploration with or without vision (see Klatzky, Lederman and Reed, 1987). Haptic identification of different properties of the objects is possible, each being detected by means of specific exploratory procedures (EPs). For example, *enclosure* is a necessary procedure to detect global shape; *contour following* allows a good detection of precise shape while *lateral motion* on the object surface is sufficient to detect texture. However, not of all these exploratory procedures are exhibited by the infants. Therefore, it is difficult to know which properties the infants can detect. Perhaps, they detect only one or two properties when they are holding an object in their hands.

Texture and shape are two amodal properties processed by both vision and touch but they present several dissimilarities in its functioning. In adults, vision is specifically suited to

processing the spatial or macrogeometric properties of objects (shape, volume, size) and can process many objects at a glance. In contrast, touch is excellent for providing information about the material or microgeometric properties of objects (texture, hardness, weight, temperature) but must process each object in sequence (Klatzky et al., 1985; 1987). In this paper, we mainly focus on object *shape* because shape allows object identification and is the basis for object categorization. Texture also allows identification and discrimination between two objects, but only when they are the same shape.

Studies in Infancy

In newborns and young infants, grasping and avoiding reflexes used to be regarded as the dominant behaviors mediating interactions with the environment. The grasping reflex in neonates looks like the adult's *enclosure* procedure. Newborns strongly close their fingers on an object or an experimenter's finger. Therefore, according to Katz (1925), as well as Roland and Mortensen (1987), it is impossible to perceive the fine details of an object, or even recognize an object with a single grasp. The tactile information about object shape is sampled sequentially by several fingertips sweeping over the object's surface in different directions with different velocities. In these conditions, grasping may be insufficient to detect fine features. However, several grasps may be perfectly adequate to perceive global shape.

Method

Beyond hand reflexes, newborns are able to handle a small object. To reveal such an ability, we applied a habituation and dishabituation procedure to the manual mode, just as it is used in the visual mode (see Streri and Pêcheux, 1986a). Infants were seated in a rigid seat and an experimenter put a small object in their right or left palm. Newborns rarely tried to look at an object that they held. When necessary, the experimenter hid the object with her hands to prevent the baby from looking at it. Older infants often tried to look at the object, and therefore we used a white cloth screen to separate the visual field from the tactile field, allowing infants to explore the objects freely without seeing them. Thus, all information was gained by the hands alone.

The habituation/dishabituation procedure involved two phases. The habituation phase included a series of trials in which the infants received a small object in one hand. A trial began when the infant held the object and ended when the infant dropped it or after a duration defined by the experimenter. This was repeated several times. As a consequence, the habituation process entailed several grasps of a determined duration. Usually, the minimum duration for a simple grasp was 1 sec of holding and the maximum was 60 sec or 90 sec according to the infant's age. The inter-trial intervals were short (between 4 and 10 seconds). Over the course of these trials, we observed a decrease in holding times until a criterion defined by the experimenter was reached (75% decrease in our studies). The total holding time was taken as indicator of familiarization duration, without including the inter-trial intervals. The decrease in holding times was considered as revealing the infants' abilities to memorize the shape and recognize it. Moreover, it is now well established that habituation and memory processes are closely linked, revealing a form of mental representation of stimuli

(cf. Bornstein and Benasich, 1986; Pascalis and De Haan, 2003; Rovee-Collier and Barr, 2001). The mean number of trials to reach habituation was between four and fifteen trials and often varied according to the complexity of shapes. Then, in the dishabituation phase, a novel object was put in the infant's hand. If an increase in holding time of the novel object was observed, we inferred that a reaction to novelty was revealed and that the baby noticed the difference between the two objects. This procedure, controlled by the infant, is effective for revealing the early discriminatory capacities of young babies (see Streri, 1993, for a review). As a consequence, beyond the grasping reflex, young infants can process information about the shape of objects.

Results

Streri, Lhote, and Dutilleul (2000) showed that newborns (the youngest was 16-hours old) were able to detect differences in the contours of two small objects (a smoothly curved cylinder versus a sharply angled prism) with both the right and left hands. Habituation and test phases were performed with the same hand. After habituation with an object (the cylinder or prism) placed in the right or left hand, confirmed by two more trials, a novelty reaction was observed when a new object (the prism or cylinder) was put in the same newborn's hand. So, this was the first evidence of habituation and reaction to novelty that was observed with the left as well as the right hand in newborns. Newborns were able to discriminate between the curvilinear vs. rectilinear contours of small objects. As a consequence, we can conclude that haptic memory in its manual mode is also present from birth.

In the first six months after birth, the young baby is also capable of a reasonably good performance in the detection of other discrepancies between shapes. From the age of two months, geometric shapes (e.g., curvilinear vs. rectilinear) and topological relations (e.g., full shapes vs. shapes pierced with a hole) are well differentiated (Streri, 1987; Streri and Milhet, 1988). At this age, the baby is also capable of discriminating a volumetric object (a cotton reel) from a flat object (a cross) (Streri and Molina, 1993). At five months, similar performances with the same shapes are observed.

However, all these performances do not mean that the baby has a clear representation of what is being held in the hand. Because young infants are unable to realize the necessary integration and synthesis of information required in working memory under haptic exploration, shape perception is probably partial or limited to the detection of clues such as points, curves, presence or absence of a hole, etc. The information gathered is provided from enclosure of the object, which seems to be an effective exploratory procedure for such a performance. To obtain a good representation of object shape, *contour following* is a better exploratory procedure (Lederman and Klatzky, 1987). Contour following has never been observed in young infants working with or without vision.

When two-handed exploration is possible, from the age of four or five months, the baby can hold a voluminous or large-sized object. In Streri and Spelke's (1988) experiment 1, infants were presented with two rings, one in each hand, under conditions that masked their view of the rings and their own bodies. The rings were connected either in a rigid or a flexible device (by a wooden bar or elastic band). A habituation/dishabituation procedure was used. Infants were first allowed to manipulate either the rigid or the flexible connected rings at will on a series of habituation trials. Each trial ended when an infant dropped a ring, and the trial

series ended when their manipulation times declined to a habituation criterion. Then, infants were presented with the novel display for the second phase. Owing to the infants' active exploration on objects involving the shoulder, the arm and the hand, they are able to discriminate between the objects manipulated according to their rigid or their flexible properties.

Conclusion

To sum up, from birth infants are able of encoding, remembering and recognizing a certain amount of information gathered on object shape. The grasping reflex, involving rough exploratory procedures such as enclosure with light squeezes/releases on objects, is sufficient to detect similarities and differences between objects. Consequently, the processes such as habituation, discrimination and memorisation appear to be similar in the manual and visual sensory modalities. Infants can detect invariants in the tactile as in the visual modality, revealing the same competencies in the information processing of some properties of objects such as their shapes. This last conclusion is important: because the processes appear to be similar in the two modalities, we can ask about how infants transfer information across the haptic and the visual sensory modalities.

We analyze two kinds of relation: first, the interactions between the haptic and the visual mode in cross-modal transfer tasks. These abilities represent an important aspect of perception. They allow for economical and adaptive behaviours with surrounding objects, and lead to a unified and coherent perception of the environment. Second, we attempt to know if haptic cognition exists in infancy like visual cognition in situations where infants cannot haptically process all information on the objects. Cross-modal transfer methodology from touch to vision was used because visual recognition can reveal information processed by the hands.

2. CROSS-MODAL TRANSFER OF SHAPE BETWEEN TOUCH AND VISION

"... It is important to note that the ability to integrate cues from different sensory modalities did not arise with the appearance of humans. Rather, it is an ancient scheme that antedates mammals and even the evolution of the nervous system... In fact, it would be unprecedented to find an animal in which there exists a complete segregation of sensory cortex." (Stein and Wallace, 2001, p. 107).

Since the first evidence of cross-modal transfer of shape was in adult nonhuman primates (Cowey and Weikrantz, 1975; Davenport and Rogers, 1970; see Stein and Meredith, 1993), it is clear that language is not a necessary condition for sensory integration. Actually, various forms of sensory integration have now been documented. For example, transfer between touch and vision has been found in apes (Davenport, Rogers and Russel, 1975) as well as in monkeys (Murray and Mishkin, 1985; Gunderson, Rose, and Grand-Webster, 1990). Intersensory integration between auditory and visual stimulation has been observed in infant and adult rats (Spear and McKinzie, 1994) and also in birds (see Lickliter and Banker, 1994).

Rodents are able to detect intersensory equivalence based on a variety of amodal stimulus attributes such as time, number, rate and location in cross-modal transfer tasks (see Tees, 1994). However, the question of the unity of senses at birth in human beings is not answered.

First, a Philosophical Question

For several centuries, this question has been addressed by philosophical answers to Molyneux's famous question: will a person born blind and recovering sight as an adult immediately be able to distinguish visually between a cube and a sphere? (Gallagher, 2006; Proust, 1997). But Diderot (1749-1792), the first philosopher to compare the blind person to a neonate, contended that there is no doubt "that vision must be very imperfect in an infant that opens his/her eyes for the first time, or in a blind person just after his/her operation". Diderot was right when he said that newborn's vision is very imperfect. However, many experiments have since provided evidence that neonates perceive several elementary properties of the world, such as face, colour, shape, movement, etc. (see Slater, 1998). Moreover, Molyneux's question describes precisely the cross-modal task from hand to eyes in infancy. Although newborns are not directly comparable to congenitally blind people (see Gallagher, 2006, for a discussion), if they are able to form a perceptual representation of the shape of objects from the hand and to recognize it visually, a positive answer to Molyneux's question would be evidenced. A positive answer would mean that a link between the hands and the eyes exists before infants have had the opportunity to learn from the pairings of visual and tactual experiences.

For a long time, the answer to Molyneux's question was negative. According to the empiricist model, three arguments have been proposed. 1. The neonate's experience is confused; 2. The sensory modalities do not naturally communicate; 3. Molyneux's problem receives a negative answer because that experience in the manual mode (considered as the most robust modality to really know the world) is not sufficiently developed to educate the visual modality to perceive.

The Infants' Answer

More recently, Molyneux's question has received several positive empirical answers. Cross-modal transfer of texture (smooth vs. granular) and substance (hard vs. soft) from the oral modality to vision has been shown in one month-old infants (Meltzoff and Borton, 1979; Gibson and Walker, 1984). Two month-old infants were able visually to recognize the shape of an object that they have previously manipulated with their right hand (Streri, 1987). However, several questions regarding intermodal transfer remain. First, research on the newborn's vision suggests that babies might have connected some information between sensory modalities over one or two months. Second, the cross-modal transfer data in oral-visual transfer of texture were sceptically received and the results seemed weak, in that they have not always been reproduced (see Maurer, Stager and Mondloch, 1999). Third, mouthing behavior involves different exploratory procedures from handling, which are more complex and various. These discrepancies suggest that information processing by the two modes of exploration might not be developed in a similar manner or have the same function. Finally,

according to the Klatzky and Lederman (1993) classification, texture and substance are material properties and not geometric properties, thus requiring different exploratory procedures.

Experiments

Recently, Streri, and Gentaz (2003) conducted an experiment on cross-modal recognition of shape from the right hand to the eyes in human newborns. They used an intersensory paired-preference procedure that included two phases (Spelke, 1976): a haptic familiarization phase in which newborns were given an object to explore manually without seeing it, followed by a visual test phase in which infants were shown the familiar object paired with a novel one for 60 seconds. Subjects were 24 newborns (mean age: 62 hours). Tactile objects were a small cylinder (10 mm in diameter) and a small prism (10 mm triangle base). The sizes of the objects were adapted to the sizes of the newborns' hands. Because the newborns' vision is immature and their visual acuity is weak, visual objects were the same 3D objects, but much larger (45mm triangle base and 100mm in length for the prism and 30mm in diameter and 100mm in length for the cylinder) (see Table 1a).

Table 1. Cross-modal recognition of object shape

Ages	Objects	Touch/vision	Vision/touch
Newborns			
a. Streri & Gentaz (2003) <i>Somatosensory and Motor Research</i>		+	
b. Streri & Gentaz (2004) <i>Neuropsychologia</i>	Right hand Left Hand	+	
c. Sann & Streri (2007)		-	
		+	-
2-Month-olds			
d. Streri (1987) <i>British Jour. Developmental Psychology</i>		+	-
e. Streri & Milhet (1988) <i>L'Année Psychologique</i>		+	-
f. Streri & Molina (1993) <i>Perception</i>		+	+ if pictures - if objects
5-Month-olds			
g. Streri & Pêcheux (1986) <i>British Jour. Developmental Psychology</i>		-	+

An experimental group (12 subjects) received the two phases successively (haptic then visual) whereas a baseline group (12 subjects) received only the visual phase. The comparison of looking times between the two groups allowed us to provide evidence of cross-modal recognition of shape from hand to eyes in the experimental group.

Results showed that the newborns in the experimental group looked at the novel object for longer than the familiar one. In contrast, the newborns in the baseline group looked equally at both objects. Moreover, in the experimental group, infants made more gaze shifts toward the novel object than the familiar object. In the baseline group this was not the case. The results suggest that newborns recognized the familiar object through a visual comparison process and through a comparison between the haptic and visual modes. Moreover, the discrepancy between the size of visual and tactile objects was not relevant for cross-modal recognition. Shape alone seems to have been considered by newborns.

In conclusion, newborns are able to transfer shape information from right hand to eyes before they have had the opportunity to learn the pairing of visual and tactual experiences. These results challenge the empiricist philosophical conception and modern connectionist models (McClelland, Rumelhart and Group, 1986; Elman, 1996) that sensory modalities cannot communicate in newborns. The results reveal an early developing ability, largely independent of common experience, to detect abstract amodal higher-order properties of objects. It is a necessary prerequisite to the development of knowledge in infancy. At birth, the various perceptions of objects are unified to make the world stable.

How should we interpret this result? Several explanations have been proposed:

1. Maurer (1993) suggested that newborns cannot yet distinguish among the various senses. On this view, early cross-modal transfer is based on a lack of distinction rather than on a cross-modal recognition of objects. A synesthesia phenomenon would be more appropriate to understand the relations between sensory modalities: "... The newborn's senses are not well differentiated but are instead intermingled in a synesthetic confusion. [...] Energy from the different senses, including the proprioceptive sense of his or her own movement, is largely if not wholly undifferentiated: the newborn perceives changes over space and time in the quantity of energy, not the sense through which it arose" (Maurer, 1993, p 111-112). The phenomenon of synesthesia has been described as a "mixing" of the senses (Rich, Bradshaw, Mattingley, 2004) or as being evidenced in a person who experiences sensations in one modality when a second modality is stimulated, even though no physical stimulation in the first modality is presented (Marks, 1975; Ramachandran & Hubbard, 2001). The most common form of synesthesia is known as *colored hearing*, where speech sounds or music produce colored visual images as well as auditory perceptions.
2. Meltzoff (1993) proposed the Active Intermodal Matching hypothesis (A.I.M.), because in the experiment on cross-modal transfer (Meltzoff and Borton, 1979), one month-old infants matched what they saw and what they explored orally (preference for the familiar texture). As a consequence, young infants use a supramodal code that allows them to unify information processed from different sensory modalities in one common framework. The same mechanism explains neonatal imitations, such as tongue protrusion or mouth opening. According to

Meltzoff's hypothesis, imitation taps perception, cross-modal coordination and motor control. Early imitation is mediated by A.I.M. and young infants use the cross-modal equivalence between the dynamics of the visual stimulus and the motor response that infants generate and feel.

3. E. J. Gibson (1969) suggested that infants are able to abstract amodal or common information. Abstraction of common information involves equivalence between modalities with regard to amodal properties such as location, texture, movement, shape, duration, etc. Since Gibson's suggestion, the concept of amodal perception is often used to describe the link between modalities. A common percept independent from any one sense is created.

To draw a conclusion from our data, we have to confront them with these three explanations. It is necessary to examine whether cross-modal transfer is a general property of the newborn human brain or whether it is evidenced only in certain directions of transfer. In concrete terms, (1) if newborns cannot distinguish between senses then, in cross-modal transfer tasks, whatever the first stimulated modality, recognition should be evidenced in the second modality. (2) The same argument can be taken up for testing the concept of amodal perception: a bi-directional transfer should be evidenced. (3) If A.I.M. hypothesis is correct, a preference for the familiar object should be shown in the recognition test phase – infants matching the felt (or seen) object with the seen (or felt) object.

In a first experiment, Streri and Gentaz (2004) tested for cross-modal transfer from the left hand to eyes as well as transfer from the right hand (see Table 1b). Twenty-four newborns had the tactile habituation phase with the left hand, 24 other newborns had it with the right hand and 12 newborns did not receive a tactual habituation phase. In the visual phase, all newborns looked at the familiar object and at the novel object in four sequential trials (one object per trial). Cross-modal recognition was again evidenced from the right hand: Newborns looked longer at the novel object. No visual recognition was evidenced from infants in the left hand group. In the control group, newborns looked equally at the two objects. The interpretation of the handedness factor at birth is very difficult (Streri and Gentaz, 2004). Some authors suggested that handedness might be determined by foetal position (Michel & Goodwin, 1979). Two-thirds of infants are born in a left vertex presentation, which is probably also their position in the womb 3-4 weeks prior to birth. It has been suggested that, due to the foetal position, the left arm is stuck to the mother's back and consequently receives a lesser flow of arterial blood than the right arm. Other studies in connected fields also observed asymmetries favouring the right side before and after birth (Streri, 1993). Newborns present a spontaneous preference for lying with their head turned toward the right while supine (Coryell & Michel, 1978; Gesell, 1938; Turkewitz, Gordon, & Birch, 1965). Handedness in cross-modal transfer from hand to eyes might have the same origin.

In another and recent experiment, Sann and Streri (2007, experiments 1 and 2) tested the transfer from eyes to hand and from hand to eyes to ascertain whether a complete primitive unity of the senses would be shown (see table 1c). After a haptic habituation to an object (cylinder or prism), infants saw the familiar and the novel shape in alternation. After a visual habituation with either the cylinder or the prism, the familiar and the novel shape were put in the infant's right hand. The tactile objects were presented sequentially in an alternating

manner. Following haptic habituation, a visual recognition was again observed while following visual habituation, no haptic recognition was found.

Discussion

The results bear on the three models described earlier.

1. An account that relies on a confusion of the senses is not supported. Haptic inputs are transferred to the visual modality but the reverse is not true. The senses are not mixed. Plausibly, synesthetic correspondences between sensory modalities, namely between the auditory and visual modalities, exist in children (Mondloch and Maurer, 2004). But actually, there is no evidence that the newborn's perception is synesthetic. Our results cannot stem from synesthesia for several reasons. Some of these correspondences can be attributed to intensity matching, but shape is a structural property that cannot be defined in terms of "intensity of the stimulation". According to Ramachandran and Hubbard (2001), synesthesia is a sensory effect rather a cognitive one based on memory associations. Our cross-modal transfer tasks between touch and vision with successive presentations need cognitive processes such as memory and comparison processes. Such processes are not involved in an intersensory paired-preference procedure as used in Mondloch and Maurer's (2004) experiments where the visual and auditory stimulation are simultaneously presented. Nevertheless, several forms of intersensory integration are possible at birth because intersensory integration is not a unitary process (see Lewkowicz, 2000, for a review).
2. Intermodal matching is not possible because the transfer is not reciprocal. A felt object is matched with a seen object but a seen object is not matched with a felt object. A common framework may exist, but the matching process is not reciprocal as regards the object properties, at least in the case of cross-modal transfer of shape information. Moreover, in our experiments, newborns and older infants looked more at the novel object than the familiar object unlike the Meltzoff and Borton's (1979) experiments.
3. Detection of amodal information seems to be the best supported hypothesis because habituation and dishabituation are observed in both modalities. Newborns detect invariants whatever the modality that receives information. But this hypothesis must be made more precise. How amodal information is perceptually linked since transfer is not reciprocal?

Our results suggest that the similarity of processes does not necessarily lead to the similarity of representations. Information processed by vision is, from birth, immediately global and complete (Slater, Mattock, Brown and Bremner, 1991), whereas information processed by touch, if it is global thanks to the grasp, it is also limited to the stimulation of skin receptors. Moreover, the synthesis of successive information is not realized. This discrepancy in the manner of information gathering could be the cause of non reciprocal transfer between vision and touch. A seen object can be processed as a whole and the

newborn does not manually recognize this totality from a felt feature. In contrast, an infant can visually recognize a feature of an object that he or she previously felt. Amodal perception would be obtained from the simplest processed information, that is, information gathered by the haptic modality. The amodal percept is only partial because, as we saw it, the newborn's hand is not able to gain a complete percept of the object. As a consequence, cross-modal transfer of shape between touch and vision is not a general property of the newborn human brain since it is evidenced only in one direction, from touch to vision and only from the right hand and not from the left hand.

To valid this scenario, we compared two properties (shape vs texture) by testing the bi-directionality of texture in cross-modal transfer in newborns (Sann & Streri, 2007, Experiments 3 and 4). To our knowledge, no study has examined whether a cross-modal transfer between vision and touch exists in newborns for a property other than shape, such as texture. Some results were however reported about texture processing. Molina and Jouen (1998) showed that newborns are able to modulate their manual activity on objects that vary only according to their texture. The study was based on the recording of the pressure activity level exerted on objects. To access haptic perception, they used Hand Pressure Frequency (HPF), which consists in the recording of the successive contacts between the skin and an object while the object is being explored by the hand. Results showed that a continuous high hand pressure was exhibited when newborns held smooth objects and a discrete continuous low pressure when they held granular objects. In another study, Molina and Jouen (2001) conducted an experiment to investigate intersensory functioning between vision and touch for texture information in neonates. Using HPF, they compared manual activity recorded on objects varying in texture in the presence or absence of visual information. The visual object had either the same (matching condition) or different (mismatching condition) texture information. In the matching condition, holding times increased but HPF remained unchanged. In the mismatching condition, holding times remained unchanged but HPF systematically changed during test period. Taken together, these results revealed that manual activity is modulated by vision. This experiment pointed out the newborn's ability to compare texture information between vision and touch. Using a perceptual conflict procedure, Bushnell and Weinberger (1987) found cross-modal asymmetries for both shape and texture information even on the part of infants as old as 11 months. Infants detected the difference between a smooth egg-shaped object and a fur-covered cube and between a smooth cross and a fur-covered cube (shape + texture) but did not react to the presentation of a smooth cube and a smooth cross whereas they differentiated between the smooth cube from the smooth egg. Infant's haptic exploration is not as effective on its own as when it is "directed" by visual information (Bushnell and Weinberger, 1987). Nevertheless, as these studies do not involve memory, they do not tell us anything about cross-modal transfer in infants.

A comparison between shape and texture in bi-directional cross-modal transfer tasks would reveal how information is gathered and processed by the visual and tactile modalities and, as a consequence, would shed light on the perceptual mechanisms of newborns. If the perceptual mechanisms implied in gathering information on object properties are equivalent in both modalities at birth, we can expect to observe a reverse cross-modal transfer. By contrast, if the perceptual mechanisms differ in the two modes, a non-reversible transfer should be evidenced. Thirty-two newborns participated to two experiments (16 in cross-modal transfer from vision to touch condition and 16 in the reverse transfer). The material was one smooth cylinder vs one granular cylinder (a cylinder with pearls stuck on it). The

results revealed a reverse cross-modal recognition of texture between both modalities. These findings suggest that the exchanges between the sensory modes seem to be similar for the property of texture. Why do we observe a reverse cross-modal transfer for texture and not for shape?

As regards the manner of gathering information, previous studies showed that adults perceived texture most precisely when they were permitted to move their hands in a lateral gliding motion across the surface of stimulus objects (Lederman & Klatsky, 1987; 1990). However, newborns do not display this exploratory procedure. The grasping reflex is a rough exploratory procedure but it seems sufficient to differentiate between granular vs smooth objects. The visual scanning of the surface of an object is also sufficient to differentiate a granular from a smooth object. As a consequence, our results suggest that the manner of gathering and exchanging information about texture across modalities is equivalent in touch and vision from birth. This is not the case for the shape processing. Texture is a material or microgeometric property better processed by touch than by vision (see Hatwell et al., 2003). Our results reveal that newborns process this property by the hands as well as by the eyes. Shape, a geometrical or macrogeometric property, is better processed by vision than by touch. Our results confirm also this evidence. Neuroimaging data obtained in human adults suggested there may exist a functional separation in cortical processing of micro- and macrogeometric cues (Roland et al., 1987). More recently, Merabet et al. (2004) confirmed the existence of a functional separation and suggested that the occipital (visual) cortex is functionally involved in tactile tasks requiring fine spatial judgments in normally sighted individuals. The discrepancies of findings concerning bi-directional cross-modal transfer tasks of texture and shape seem to support the neuroimaging data obtained in adults.

In conclusion, our investigation of bi-directional cross-modal transfer sheds light on the perceptual mechanisms already present at birth. Our findings suggest that links between modalities exist from birth. Nevertheless, these links do not constitute a primitive and global unity of the senses: First, cross-modal transfer is not a general property of the brain since transfer of shape information is revealed from the right hand but not from the left hand (Streri & Gentaz, 2004) and not from vision to touch (Sann & Streri, 2007; Exp. 2). Second, cross-modal transfer depends on object properties since it is fully realized with texture but not with shape (Sann & Streri, 2007). Thus, cross-modal transfer depends both on the constraints and specificities of each sensory mode and on object properties.

The Development of Cross-Modal Transfer between Touch and Vision

Other research was performed using a bi-directional cross-modal transfer task, from hands to eyes and from eyes to hands with two month-old babies (Streri, 1987, exp. 2) and with 4 to 5 month-olds (Streri and Pêcheux, 1986b). The findings in bi-directional cross-modal transfer tasks have revealed that two month-old infants visually recognize an object they have previously held (Streri, 1987, exp. 2), but the tactile recognition of an already seen object is not observed (see table 1d - 1e). A plausible explanation of these results of cross-modal transfer is that, as in newborns, the levels of representation reached by each modality are not equivalent sufficient to exchange information between sensory modalities. This hypothesis is validated by the fact that, if a two month-old baby is presented with a degraded visual stimulation (a bi-dimensional sketch of an 3D object) that can give a blurred percept

(see Table 1f), tactile recognition is possible, which is not the case with a visual volumetric object (Streri and Molina, 1993). Our results are supported by the Ernst and Banks's model (2002) of human adults' performances. In this study, adults performed an intersensory integration task comparing the size of objects between touch and vision. Results revealed that visual capture was observed when the visual stimulus was clear ("noise-free") and haptic capture was observed when the visual stimulus was quite noisy. In other words, the sensory modality that dominates over people's performance is the one that carries the lower level of variance.

At five months, the asymmetrical relationship is the opposite. For the first time, a baby becomes capable of tactually recognizing an object already looked at, but the reciprocal touch-vision relationship temporarily disappears (Streri & Pêcheux, 1986b) (see Table 1g). Touch-to-vision transfer occurs at birth and at two months of age but disappears at five months, whereas the infant manually recognizes an object he/she has already seen. The baby is at a stage when manual skills dominate exchanges with the environment. For example, the coordination between vision and touch is extensively practised: when an object is near to babies, they will reach out to grasp it immediately and when an object is put in their hands, they will look at it. One hypothesis would be that manual skills in reaching for grasping the seen objects temporarily interferes with the perceptive function of the hand that appears from birth. The lack of touch-to-vision transfer at 5 months is transitory because at six months and over, touch-to-vision transfer is once again observed (Ruff and Kohler, 1978; Rose, Gottfried and Bridger, 1981a).

Failures in reciprocal cross-modal transfer are again found in 1 year-olds (Rose and Orlian, 1991). In this study, infants received four tasks: after visual familiarization, infants were tested either for visual recognition (V-V) or cross-modal transfer (V-T); after tactual familiarization, they were tested either for tactual recognition (T-T) or cross-modal transfer (T-V). The results indicated that the V-V condition was the easiest and the V-T condition was the more difficult. T-T and T-V conditions gave intermediate results.

Several reasons for these discrepancies in infancy were proposed. 1. The eyes processed information about shape faster and better than the hands (Streri, 1987; Rose & Orlian, 1991). 2. The level of representation is not equivalent in both modalities. The tactile percept is vague or partial whereas the visual percept is already precise and global (Streri, 1987; 1993). 3. The asymmetry in cross-modal transfer ($T-V > V-T$) occurs because the eyes and hands pick up different object characteristics, rather than directly picking up the same invariants or amodal properties (Rose & Orlian, 1991; See also, Rose, 1994). The last two interpretations are not contradictory. Because the necessary exploratory procedure to detect precise shape (contour following) is not displayed in young infants, they might gather information partially with their hands and more completely with their eyes, thus perceiving different invariants. As a consequence, information initially gathered and stored in one sense is elaborated in such a way as to become unavailable to another.

In children, the results are contradictory: Some studies have shown that they perform significantly better on visual-tactual transfer than on tactual-visual transfer (Rudel and Teuber, 1964, 1971; Stoltz-Loike and Bornstein, 1987), other studies do not report such differences in performance (Rose, Blank & Bridger, 1972; see also Freides, 1974 for a review). In contrast, adults' performances are often less good in the V-T condition than in the T-V condition (Connolly and Jones, 1970; Jones and Connolly, 1970; Juurmaa & Lehtinen-Railo, 1988; Newham & MacKenzie, 1993; cf. Hatwell, 1994). Recently, a PET study

revealed that the human brain mechanisms underlying cross-modal discrimination have two different pathways depending on the temporal order in which stimuli are presented (Kawashima et al., 2002). The dorsal premotor cortex, the ventral premotor cortex, and the inferior temporal cortex of the right hemisphere were activated during VT but not during TV. Moreover, psychophysical measures on the same adult subjects provided evidence that the percentage of correct responses was the lowest during VT compared to that during TV. These results are recently confirmed by an fMRI study (Miquée et al., 2007).

Thus, the T-V condition appears better performed than the V-T condition from birth and throughout life for cross-modal information of shape. From 1968, Lobb suggested that the presumed superiority of transfer in the tactual-visual sequence was an artefact of visual superiority for shape perception. More precisely, Connolly and Jones (1970) claimed that information is translated into the form required immediately by the task and that this is a function of order of presentation. Information reaching a less adept modality (the haptic mode) is translated into the code of the most adept modality (the visual mode). This implies that the development of cross-modal functions consists of learning to perform the translation. Our results obtained in bi-directional cross-modal transfer of shape from birth and beyond support this point of view.

In short, coordination between touch and vision exists at birth. The links between the two modalities are not complete however, because they depend on the efficiency of information processing in each modality (vision or touch). The relations between sensory modalities are mainly determined by the haptic mode in infancy as well as in children and adults. Transfer of object shape is rarely reciprocal because the manner of gathering and memorizing information in the visual and haptic sensory modalities is quite different, but coordination is always present either from the hands or from the eyes. As a consequence, intersensory integration is dynamic in the course of development.

This conclusion concerns mainly the shape of objects. Although other research has to be performed with other object properties such as material properties (texture or substance) from birth, these findings seriously undermine the hypothesis of the primitive unity of the senses, while affirming that the links between the sensory modalities are always present. Our results suggest that amodal perception is an obligatory cognitive process (Fodor, 1983) that allows an organism to adapt to its environment. But, this process becomes flexible and penetrable in the course of development, because the hands are both the motor system by which reaching for and grasping are carried out and the active perceptual system through which spatial information is gathered from the environment.

Haptic Cognition in Infancy

The study of intermodal perception focuses on how and when infants perceive information from different modalities as belonging to a single unified object representation (Hatwell, 1994). Haptic and visual receptors are stimulated and infants have to create a common percept or representation of the object that they see and feel. Physical reasoning is the study of infants' expectations for the way that objects should move and interact in the environment. These studies focus on what kind of knowledge infants possess about the physical world. For example, the knowledge that objects are solid, bounded entities that maintain their physical properties through space and time leads infants to attend to certain

types of information when viewing physical events (Spelke et al. 1992; Spelke, 1994). Intermodal perception and physical reasoning in young infants have been developed relatively independently. Recently, using a violation-of-expectation method, Schweinle and Wilcox (2004) examined 5.5 month-olds' abilities to coordinate information from the tactile and visual modalities and use their intermodal object representations to interpret physical events. Infants were tactilely presented with a ball that was either rigid or compressible. Following the tactile exploration trials, infants viewed a test event in which the ball moved back and forth through a tunnel. The ball was either larger or smaller than the tunnel opening. When the ball was much larger than the tunnel opening, the infants correctly judged that the compressible ball, but not the rigid ball (violation of expectancy) could pass through the tunnel and when the ball was much smaller than the tunnel opening, the infants correctly judged that both the compressible and the rigid ball could fit through the tunnel. Thus, infants are capable of using information about object substance encoded tactilely to interpret a passing-through event presented visually.

In a different manner, experiments show that the haptic system has its own encoding processes and that infants can use their hands to gain knowledge of the world in the same manner as vision. Perception of partially occluded objects provides the point of departure for these studies of haptic cognition. To study infants' perception of unity under occlusion, Kellman and Spelke (1983) developed a method using habituation and recovery of visual attention. This method included two phases. In the habituation phase, infants saw a display containing a rod behind an occluder. The rod moved in translation behind the occluder. In the test phase, infants were presented with two visual displays: a complete rod or two separate pieces corresponding to the visible areas present in the occlusion display. The logic was the following: if in the habituation phase, infants thought they saw a complete rod, they should look less at the complete rod than at the separate pieces. The reverse is also true. If in the habituation phase, infants thought they saw two visible pieces, they should look longer at the complete rod than at the separate pieces in the visual test.

All the experiments provided evidence that 4 month-old infants consider the occluded rod as complete in the condition where it is in translation behind a stable occluder. When the occluder moved in a contingent manner with the rod or when the occluder moved and the rod was stable, or when the whole display was stable, then perception of the complete rod was not clear. Infants evidently perceive objects by analyzing the motions of surfaces so as to form units that move as wholes, but not by analyzing the colors, textures, and shapes of surfaces so as to form units of maximal simplicity and regularity. So, when the visible edges of these two parts of occluded rod were not linked according to similarity or any other Gestalt principle, but they were moved back and forth with a common lateral translation, unity was perceived (see Kellman and Arterberry, 1998, for a review). As a result, common motion of the rod alone specifies object unity. Subsequent research (Kellman, Spelke, and Short, 1986) sought out the motion relationships that underlie perception of object unity. They found that rigid translations along any axis, including translations in depth, led to infants' perception of unity. In contrast, rotary motion did not lead to infants' perception of unity until they were at least 6 months old (see Eizenman and Berthenthal, 1998). All the results provided evidence that young infants are able to complete missing information and to conceive a partially seen object in its totality. This ability also occurs in other species, such as the domestic chick (Regolin and Vallortigara, 1995).

In a series of experiments, we adapted these designs from visual perception to examine haptic perception. We used the cross-modal paradigm to discover whether perception of unity is amodal and involves a similar process in the haptic mode under the same conditions as the visual mode. Four to 5 month-old infants held two rings, one in each hand, under a cloth that blocked their view of the rings and the space between them. In one condition the rings were rigidly connected and moved together, whereas in the other condition the rings could be moved independently (see Table 2a). After exploring the rings haptically, infants received, in an alternating manner, a visual test with pairs of rings that were connected or separated. Across all experiments, infants explored the rings bimanually during habituation, producing patterns of rigid or independent motion, but they never touched the connection. The experiments provided evidence that infants perceive the unity and boundaries of objects by detecting the motion patterns that they themselves produced. Infants who explored the independently moveable rings perceived two distinct objects, while infants who explored the rigidly moveable rings perceived a single object (Streri and Spelke, 1988).

In the other experiments, Streri and Spelke (1989) tested whether figural goodness or motion relationships predominate in the haptic modality. Either the rings moved rigidly together and had the same substance, texture, weight, etc. or the rings differed in all these characteristics (see Table 2b). In the haptic modality as in the visual modality, infants appear to perceive object unity by analyzing motion relationships but not by analyzing figural goodness.

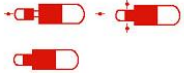
Streri, Spelke, and Rameix (1993) sought out the kind of motion relationships that underlie unity perception in the haptic mode. In five experiments, 4 to 5 month-old infants manipulated a device made up of a small and a large surface that they could hold in each hand by a handle. In one condition, the surfaces were rigidly connected. In the second condition, the handles could be moved by sliding the small surface vertically along the large surface. In the final condition, the small surface could be pulled away from the large surface and pushed towards it (see Table 2c). In a passive condition, the experimenter held and moved the device. After haptic habituation to the device, infants received in the visual modality the connected device or the two separated surfaces. The findings revealed that infants who explored the rigidly connected device visually perceived the display as a single unit. When infants explored the device either by sliding or by moving apart the two elements, they perceived it as two units. When the experimenter moved the display, the infants' responses were indeterminate. Infants looked equally at the two visual displays.

Finally, Streri, Gentaz, Spelke, and Van de Walle (2004) investigated infant's perception of unity in relation to two properties of the assemblies. First, we varied whether the two rings were connected to the same pivot point or to two spatially separated pivot points. Second, we varied whether the two rings underwent a single rigid, rotary motion, opposite rotary motions (like scissors), or independent rotary motions. We asked whether infants perceive object unity in the haptic mode on the basis of patterns of rotary motion, and whether their perception is affected by specific spatial and temporal properties of the motion patterns (see Table 2d). When the infants explored the unconnected independent movement display, they perceived two units. When the infants explored the connected rigid movement display, they visually perceived one unit. When the infants explored the connected independent movement display or the connected opposite movement display, their perception was ambiguous. The findings suggest that all rigid rotations are potentially informative to infants. The perception of object unity is influenced by three spatio-temporal properties of rotary motion: the presence or

absence of a common fixed point of rotation, the presence or absence of a common pattern of rigid displacement, and the presence or absence of a contingent motion.

In short, with their hands considered in isolation, infants are able to detect some physical constraints on the movement of simple or composite objects. They are able to complete missing information thanks to their own movements on the objects manipulated only with their hands. They possess representational capacities that are similar in the visual and haptic sensory modalities.

Table 2. Perception of object unity in the haptic mode

Ages	Haptic Displays	Visual Displays	Results
4-Month-olds a. Streri & Spelke (1988) <i>Cognitive Psychology</i> b. Streri & Spelke (1989) <i>Child development</i> c. Streri, Spelke & Rameix (1993) <i>Cognition</i> Active condition Passive condition	 Rigid connection  Flexible connection	 	1 unit 2 units
			One unit
		 or 	2 units 1 unit ambiguous
4/5 Month-olds d. Streri, Spelke, Gentaz & Van de Walle (2004) <i>Quarterly Journal of Experimental Psychology</i>	 Unconnected Independent movement		2 units
	 Connected Rigid movement		1 unit
	 Connected Independent movement	or	ambiguous
	 Connected Opposite movement		ambiguous

Infants' thinking ability has recently been explored in another domain of competences, that of the detection of numerosity. Using habituation-dishabituation procedure, several visual studies have provided evidence that infants, as early as birth, are sensitive to number and discriminate between two vs three points (Starkey & Cooper, 1980; Antell & Keating, 1983) or can compute subtraction or addition when 5-month-olds (Wynn, 1992). However, there is a debate about whether this ability results from sensitivity to perceptual features or from a more general abstract representation of numerosity. One way to answer this question is to examine whether infants recognize cross-modal numerical correspondences. A first attempt to examine such an ability in infants was carried out by Starkey, Spelke, and Gelman (1983, 1990). In two series of experiments, they provided evidence that 6-to 8-month-old infants can match a number of sounds to the same number of visual objects. Infants were habituated to pictures of two or three heterogeneous objects while hearing two or three drumbeats. Infants looked longer at the pictures with the number of items corresponding to the number of drumbeats. This result is crucial because it suggests that infants have an abstract, amodal mechanism for numerical representation across the visual and auditory modalities. Thus, this mechanism

might depend on cognition rather than on perception. Do infants show similar numerical abilities in the haptic mode? A recent research investigated infants' ability to abstract numerical information from a set of objects presented in the haptic sensory mode (Féron, Streri, & Gentaz, 2006). 4½-to 5-month-old infants were first haptically familiarized with two or three objects with different shapes presented one by one in their right hand. Then, they were presented with visual displays containing two or three objects, in alternation. To prevent a possible cross-modal transfer of shape, the visual objects were a mix of topological and geometrical characteristics of the haptic objects. For purposes of comparison, infants in a baseline condition also received the two visual displays but without any previous haptic familiarization. Results showed different patterns of looking preferences in the three conditions. In both conditions of haptic familiarization, infants looked longer at the display whose number of objects did not match the number of objects previously held, whereas infants in the baseline condition did not show significant preferences for any of these two displays. These findings reveal that infants can count the number of different objects received in their hand and detect numerical correspondences between a haptic sequence of objects and a visual scene. An amodal mechanism of detection of numerosity exists in the haptic as well as in the visual mode but also in the auditory mode (see Starkey, Spelke & Gelman, 1983 ; 1990).

In the two different domains presented, young infants have been found to detect an abstract piece of information independently of the properties of the handled objects. The infants are able to abstract and fulfill missing information from complex events that they produce with their hands. In consequence, perception of object boundaries as well as detection of numerosity rest on the same processes through vision and touch. These studies seem to indicate that when infants have to think about things, the mechanism involved transcends the specificities of sensory modalities. In other words, a common, amodal process seems to underlie the infant's thought in various cognitive tasks.

CONCLUSION

The purpose of our research has been to obtain a developmental overview of the sighted infant's manual system working without vision. Our studies have allowed us to compare and delimit the performances of each system considered in isolation and to test also their efficiency or, in contrast, their impairment of another system. To sum up, this paper has provided evidence for various abilities of hands in infancy from birth. The newborns' haptic mode is not limited to oral exploration. On the contrary, our research has revealed several competencies of infants' manual exploration. Newborns and infants, while holding an object, are able to gather some properties of this object. Some properties are specific to the haptic mode – for example temperature – and can be processed only by touch. Other properties such as shape or texture are amodal (i.e. gathered and processed by two modalities). As regards the object shape, our findings reveal that newborns and older infants are able to detect invariants by their manual exploration in the same way as by visual exploration. They discriminate between various shapes with their hands alone. They understand also, due to their bimanual exploration, that objects are solid, bounded entities that maintain their physical unity through space in the same manner as with their visual exploration. As a consequence, the cognitive

abilities of infants when they are exploring objects with their hands alone are not mediated by vision. The haptic system has its own encoding processes that are similar to those of the visual mode.

These results allow us to begin to understand how congenitally blind infants can perceive and understand the world by touch. Of course, the neurologically healthy young infants in our experiments who were working without visual input are not directly comparable to blind infants. Still, our results suggest that the haptic mode is the best candidate to substitute for their visual deficits. We suggest that when blind infants contact and explore objects with their hands, they come to perceive and understand the world.

When the sensory modalities have to interact with each other, in the cross-modal transfer tasks, our findings do not support the complete unity of senses hypothesis at birth suggested by Gibson (1966) and Gestalt theory but reveal that a link always exists between the sensory modalities. This link is not obtained due to a matching process or a confusion of the senses, but rather appears to be due to an abstract amodal percept that is mainly settled by the haptic mode. This amodal percept is not fully complete, because infants' manual exploration is limited and does not allow infants to obtain a good perception of the whole object. Moreover, the haptic mode is the less efficient mode to process shape information. The link between sensory modalities stems from a necessary, always maintained, and flexible process. Plausibly, these properties allow infants to regulate their activity in relevant ways in the course of development.

We know that infants with autism have some problem integrating information among the sensory modes. This deficit in sensory integration is probably related to their well-documented difficulty in body schema. We suggest that research on intermodal transfer tasks between touch and vision in normal infants may provide a model for this population.

REFERENCES

- Antell, S.E., & Keating, D.P. (1983). Perception of numerical invariance in neonates. *Child Development*, 54, 695-701.
- Armstrong, D.F. (1999). *Original signs: Gesture, sign, and the source of language*. Gallaudet: University Press.
- Baillargeon, R. (1995). Physical reasoning in infancy. In M. S. Gazzaniga (Ed.) *The cognitive neurosciences*. Pp. 181-204. A Bradford Book, MIT Press.
- Bornstein, M. H., & Benasich, A. A. (1986). Infant habituation: Assessments of individual differences and short-term reliability at 5 months. *Child Development*, 57, 87-99.
- Bushnell, E.W., & Weinberger, N. (1987). Infants' detection of visual-tactual discrepancies: asymmetries that indicates a directive role of visual information. *Journal of Experimental Psychology: Human Perception and Performance*, 13, 601-608.
- Butterworth, G.E., & Hopkins, B. (1988). Hand-mouth coordination in the newborn human infant, *British Journal of Developmental Psychology*, 6, 303-314.
- Caplan, P.J., & Kinsbourne, M. (1976). Baby drops the rattle: Asymmetry of duration of grasp by infants. *Child Development*, 47, 532-534.
- Carvell, G.E., & Simons, D.J. (1990). Biometric analyses of vibrissal tactile discrimination in the rat. *Journal of neuroscience*, 10, 2638-2648.

- Clifton, R.K. (2001). Lessons from infants: 1960-2000. *Infancy*, 2, 285-309.
- Connolly, K., & Jones, B. (1970) A developmental study of afferent-reafferent integration. *British Journal of Psychology*, 61, 259-266.
- Corballis, M.C. (2003). From mouth to hand: Gesture, speech, and the evolution of right-handedness. *Behavioral and Brain Sciences*, 26, 199-260.
- Corballis, M.C. (2002). *From hand to mouth: the origins of language*. Princeton: University Press.
- Coryell, J.F., & Michel, G.F. (1978). How supine postural preferences of infants can contribute toward the development of handedness. *Infant Behavior and Development*, 1, 245-257.
- Cowey, A., & Weiskrantz, L. (1975). Demonstration of cross-modal matching in Rhesus monkeys (*Macaca mulatta*). *Neuropsychologia*, 13, 117-121.
- Davenport, R.K., & Rogers, C.M. (1970). Intermodal equivalence of stimuli in apes, *Science*, 168, 279-280.
- Davenport, R.K., & Rogers, C.M., & Russell, I.S. (1975). Cross-modal perception in apes. Altered visual cues and delay. *Neuropsychologia*, 13, 229-235.
- Diderot, D. (1749/1972). *La lettre sur les aveugles à l'usage de ceux qui voient*. (the letter on blind people to sighted people). Paris: Garnier-Flammarion.
- Eizenman, D.R., & Berthenthal, B.I. (1998). Infant's perception of unity in translating and rotating displays. *Developmental Psychology*, 34, 426-434.
- Elman, J.L. (1996). *Rethinking Innateness: A connectionist perspective on development*. Cambridge, Mass: MIT Press.
- Ernst, M.O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature*, 415, 429-433.
- Féron, J., Gentaz, E., & Streri, A. (2006). Evidence of amodal representation of small numbers across visuo-tactile modalities in 5-month-old infants. *Cognitive Development*, 21, 81-92.
- Fodor, J.A. (1983). *The modularity of mind. An essay on faculty psychology*. Cambridge, Mass: MIT Press.
- Freides, D. 1974). Human information processing and sensory modality: cross-modal functions, information complexity, memory, and deficit. *Psychological Bulletin*, 81, 284-310.
- Gallagher, S. (2006). Neurons and Neonates: reflections on the Molyneux Problem. In Gallagher, S. (Ed.): *How the body shapes the mind*. Oxford: Oxford University Press.
- Geldar, F.A., & Sherrick, C.E. (1965). Multiple cutaneous stimulation: The discrimination of vibratory patterns. *The Journal of the Acoustical Society of America*, 37, 797-801.
- Gesell, A. (1938). The tonic neck reflex in the human infant. *Journal of Pediatrics*, 13, 455-464.
- Gibson, E.J. (1969). *Principles of perceptual learning and development*. New York: Academic Press.
- Gibson, E. J., & Walker, A. (1984). Development of knowledge of visual-tactile affordances of substance. *Child Development*, 55, 453-460.
- Gibson, J.J. (1966). *The senses considered as perceptual systems*. Boston: Houghton Mifflin.
- Goren, C.C., Sarty, M. & Wu, P.Y.K. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics*, 56, 544-548.

- Gunderson, V.M., Rose, S.A., & Grant-Webster, K.S. (1990). Cross-modal transfer in high- and low-risk infant pigtailed macaque monkeys. *Developmental Psychology*, 26, 576-581.
- Hatwell, Y., Streri, A., & Gentaz (2003). Touching for knowing. Cognitive psychology of tactile manual perception. Amsterdam: Johns Benjamins Publishing Compagny.
- Hatwell, Y. (1994). Transferts intermodaux et intégration intermodale (cross-modal transfers and intersensory integration) . In M.Richelle, J.Requin et M.Robert (Eds), *Traité de psychologie expérimentale*, vol 1. Pp.543-584. Paris: PUF.
- Hawn, P. R., & Harris, L. J. (1983). Hand differences in grasp duration and reaching in two- and five-month-old infants. In G. Young, S.J. Segalowitz, C.M. Corter, & S.E. Trehub (Eds.). *Manual Specialization and Developing Brain* (Vol. 17). Pp. 331-348. New York: Academic Press.
- Jones, B., & Connolly, K. (1970). Memory effects in cross-modal matching. *British Journal of Psychology* , 61, 267-270.
- Juurmaa, J., & Lehtinen – Railo, S. (1994). Visual experience and access to spatial knowledge. *Journal of Visual Impairment and Blindness*, 88, 157-170.
- Katz, D. (1925). *Der Aufbau der Tastwelt*. *Zeitschrift für Psychologie*.
- Kawhashima, M., Wanatabe, J., Kato, T., Nakamura, A., Hatano, K., Schormann, T. (2002). Direction of cross-modal transfer affects human brain activation: A pet study. *European Journal of Neuroscience*, 16(1), 137-144.
- Kellman, P. J., Spelke, E. S., & Short, K. R. (1986). Infant perception of object unity from translatory motion in depth and vertical translation. *Child Development*, 57, 72-86.
- Kellman, P., & Arterberry, M. (1998) *The cradle of knowledge*. Development of perception in infancy. Cambrige, Mass: MIT Press.
- Kellman, P.J., & Spelke, E.S. (1983). Perception of partly occluded objects in infancy. *Cognitive Psychology*, 15, 483-524.
- Klatzy, R.L., & Lederman, S.J. (1993). Toward a computational model of constraint-driven exploration and haptic object identification. *Perception*, 22, 597-621.
- Klatzy, R.L., Lederman, S.J., & Reed, C. (1987). There's more to touch than meets the eye: The salience of object attributes for haptic with and without vision. *Journal of Experimental Psychology: General*, 116, 356-369.
- Ledermann, S. J., & Klatzky, R.L. (1987). Hand movements: A window into haptic object recognition. *Cognitive Psychology*, 19, 342-368.
- Lederman, S.J., & Klatzky, R. (1990). Haptic classification of common objects : knowledge-driven exploration. *Cognitive Psychology*, 22, 421-459.
- Lewkowicz, D.J. (2000). The development of intersensory temporal perception: An epigenetic systems/Limitations View. *Psychological Bulletin*, 126, 281-308.
- Lickliter, R., Banker, H. (1994). Prenatal components of intersensory development in precocial birds. In D.J. Lewkowicz and R. Lickliter (Eds.). *The development of intersensory perception. Comparative perspectives*. Pp. 59-80. Hillsdale: Lawrence Erlbaum Associates.
- Lobb, H. Comment on the relative crossmodal transfer of a form discrimination. *Psychonomic Science*, 1968, 11, 360.
- Lommis, J.M., & Lederman, S.J. (1986). Tactual perception. *Handbook of perception and human performance*. Vol. II: Cognitive processes and performance. (ch. 31) Pp. 1-41. New-York: John Wiley and Sons.

- Marks, L.E. (1975). On coloured-hearing synaesthesia: Cross-modal translations of sensory dimensions. *Psychological Bulletin*, 82, 303-331.
- McClelland, J., Rumelhart, J., & Group, P.R. (1986). *Parallel Distributed Processing: Explanations in the microstructure of Cognition. Psychological and Biological Models*, 2. Cambridge, Mass: MIT Press.
- Maurer, D. (1993). Neonatal synaesthesia: implications for the processing of speech and faces. In B. de Boysson-Bardies et al. (eds.), *Developmental neurocognition: Speech and Face Processing in the first year of life*. Pp. 109-124. Netherlands: Kluwer Academic Publishers.
- Maurer, D., Stager, C., & Mondloch, C. (1999). Cross-modal transfer of shape is difficult to demonstrate in one-month-olds. *Child Development*, 70, 1047-1057.
- Meltzoff, A.N., & Borton, R.W. (1979). Intermodal matching by human neonates. *Nature*, 282, 403-404.
- Meltzoff, A.N., & Moore, M.K. (1977). Imitation of facial and manual gestures by human neonates. *Science*, 198, 75-78.
- Meltzoff, A.N. (1993). Molyneux' s babies: Cross-modal perception, imitation and the mind of the preverbal infant. In N. Eilan, R. McCarthy, & B. Brewer (Eds). *Spatial representation: Problems in philosophy and psychology*. Pp. 219-235. Cambridge, Mass: Blackwell.
- Merabet, L., Thut, G., Murray, B., Andrews, J. Hsiao, & Pascual-Leone, A. (2004). Feeling by sight or seeing by touch? *Neuron*, 42, 173-179.
- Michel, G.F., & Goodwin, R. (1979). Intrauterine birth position predicts newborn supine head preferences. *Infant Behavior and Development*, 2, 29-38.
- Miquee, A., Xerri, C., Rainville, C., Anton, J.L., Nazarian, B., Roth, M., Zennou-Azogui, Y., (2007). Neuronal substrates of haptic shape encoding and matching : an fmri study, *Neuroscience* (in press).
- Molina, M., & Jouen, F. (1998). Modulation of the palmar grasp behaviour in neonates according to texture property. *Infant Behavior and Development* , 21, 659-666.
- Molina, M., & Jouen, F. (2001). Modulation of manual activity by vision in human newborns. *Developmental Psychobiology* , 38, 123-132.
- Mondloch, C.J., & Maurer, D. (2004). Do small white balls squeak ? Pitch-object correspondences in young children. *Cognitive, Affective, & Behavioral Neuroscience*, 4, 133-136.
- Murray, A., & Mishkin, M. (1985). Amygdalectomy impairs cross-modal association in monkeys. *Science*, 228, 604-606.
- Newham, C., & McKenzie, B.E., (1993). Cross-modal transfer of sequential and haptic information by clumsy children. *Perception*, 22, 1061-1073.
- Pascalis, O., & de-Haan, M. (2003). Recognition memory and novelty preference: What model? In: H. Hayne and J. Fagen, (Eds). *Progress in infancy research. Volume 3*. Pp. 95-119. Mahwah, NJ: Lawrence Erlbaum Associates.
- Petrie, B.F., & Peters, M. (1980). Handedness: left/right differences in intensity of grasp response and duration of rattle holding in infants. *Infant Behavior and Development*, 3, 215-221.
- Proust, J. (1997). *Perception et Intermodalité.(Perception and intersensory relations)*. Paris : Presses Universitaires de France.

- Ramachandran, V.S., & Hubbard, E.M. (2001). Synaesthesia – A window into perception, thought and language. *Journal of consciousness Studies*, 8, 3-34.
- Rich, A.N., Bradshaw, J.L., Mattingley, J.B. (2004). A systematic, large-scale study of synaesthesia: implications for the role of early experience in lexical-colour associations. *Cognition*, 98, 53-84.
- Regolin, L., & Vallortigara, G. (1995). Perception of partly occluded objects by young chicks. *Perception & Psychophysics*, 57, 971-976.
- Revesz, G. (1950). *Psychology and art of the blind*. London: Longmans Green.
- Rizolatti, G., & Arbib, M.A. (1998). Language within our grasp. *Trends in Neuroscience*, 21, 188-194.
- Rochat, P. (1989). Object manipulation and exploration in 2- to 5-month-old infants. *Developmental Psychology*, 25, 871-884.
- Roland, P.E., & Mortensen, E. (1987). Somatosensory detection of microgeometry, macrogeometry and kinaesthesia in man. *Brain Research Review*, 12, 1-42.
- Roland, P.E., O'Sullivan, B., & Kawashima, R. (1998). Shape and roughness activate different somatosensory areas in the human brain. *Proceeding of National Academy of Sciences*, 95, 3295-3300.
- Rose, S.A. (1994). From hand to eye: findings and issues in infant cross-modal transfer. In D.J. Lewkowicz and R. Lickliter (Eds.). *The development of intersensory perception. Comparative perspectives*. Pp. 265-284. Hillsdale, Lawrence Erlbaum Associates.
- Rose, S.A., Gottfried, A.W., & Bridger, W.H. (1981). Cross-modal transfer in 6-month-old infants. *Developmental Psychology*, 17, 661-669.
- Rose, S.A., Blank, M.S., & Bridger, W.H. (1972). Intermodal and intramodal retention of visual and tactual information in young children. *Developmental Psychology*, 6, 482-486.
- Rose, S.A., & Orlian, E.K. (1991) Asymetries in infant cross-modal transfer. *Child Development*, 62, 706-718.
- Rovee-Collier, C., & Barr, R. (2001). Infant learning and memory. In: G. Bremner and A. Fogel, (Eds.) *Handbook of infant development*. pp. 139-168. Malden, Mass: Blackwell Publishing.
- Rudel, R.G., & Teuber, H.L. (1964). Cross-modal transfer of shape discrimination by children. *Neuropsychologia*, 2, 1-8.
- Rudel, R.G., & Teuber, H.L. (1971). Pattern recognition within and across sensory modalities in normal and brain-injured children. *Neuropsychologia*, 9, 389-399.
- Ruff, H.A., & Kohler, C.J. (1978). Tactual-visual transfer in six-month-old infants. *Infant Behavior and Development*, 1, 259-264.
- Sann, C., & Streri, A. (2007). Perception of object shape and texture in human newborns : evidence from cross-modal transfer tasks. *Developmental Science*, 10 :3, 398-409.
- Schweinle, A., & Wilcox, T. (2004). Intermodal perception and physical reasoning in young infants. *Infant Behavior & Development*, 27, 246-265.
- Slater, A. (1998). *Perceptual development. Visual, auditory and speech perception in infancy*. Hove, U.K.: Psychology Press.
- Slater, A., Mattock, A., & Brown, E. (1990). Size constancy at birth: Newborn infants' responses to retinal and real size. *Journal of Experimental Child Psychology*, 49, 314-322.
- Slater, A., & Morison, V. (1985). Shape constancy and slant perception at birth. *Perception*, 14, 337-344.

- Slater, A., Quinn, P.C., Hayes, R.A. & Brown, E. (2000). The role of facial orientation in newborn infants' preference for attractive faces. *Developmental Science*, 3, 181-185.
- Slater, A., Mattock, A., Brown, E., & Bremner, J.G. (1991). Form perception at birth: Cohen and Younger (1984) revisited. *Journal of Experimental Child Psychology*, 51, 395-406.
- Spear, N.E., & McKinzie, D.L. (1994). Intersensory integration in the infant rat. In D.J. Lewkowicz and R. Lickliter (Eds.). *The development of intersensory perception. Comparative perspectives*. Pp. 133-163. Hillsdale: Lawrence Erlbaum Associates.
- Spelke, E. S. (2003). Core knowledge. In N. Kanwisher & J. Duncan (Eds.) *Attention and Performance*, vol. 20. Pp. 29-55. Oxford: University Press.
- Spelke, E.S. (1994). Initial Knowledge: six suggestions. *Cognition*, 50, 431-445.
- Spelke, E.S. (1976). Infants' intermodal perception of events. *Cognitive Psychology*, 8, 553-560.
- Spelke, E.S, Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review*, 99, 605-632.
- Starkey, P. & Cooper, R.G. (1980). Perception of number by human infants. *Science*, 210, 1033-1035.
- Starkey, P., Spelke, E.S. & Gelman, R. (1983). Detection of intermodal numerical correspondences by human infants. *Science*, 222, 179-181.
- Starkey, P. Spelke, E.S. & Gelman, R. (1990). Numerical abstraction by human infants. *Cognition*, 39, 171-172.
- Stein, B.E., & Meredith, M.A. (1993). *The merging of the senses*. Cambridge: The MIT Press.
- Stein, B.E., & Wallace, M.T. (2001). Intersensory integration. Underlying neural mechanisms. In P.G. Grossenbacher (Ed.). *Finding consciousness in the Brain. A neurocognitive approach*. Amsterdam, John Benjamins Publishing Company. pp. 105-131.
- Stoltz-Loike, M., & Bornstein, M.H. (1987). The role of imagery, language, and metamemory in cross-modal transfer in children. *Psychological Research*, 49, 63-68.
- Streri, A. (1987). Tactile discrimination of shape and intermodal transfer in 2- to 3- month-old infants. *British Journal of Developmental Psychology*, 5, 213-220.
- Streri, A. (1993). *Seeing, Reaching, Touching. The relations between vision and touch in infancy*. London: Halverster Wheatsheaf.
- Streri, A., & Gentaz, E. (2003). Cross-modal recognition of shape from hand to eyes in human newborns. *Somatosensory & Motor Research*, 20, 11-16.
- Streri, A., & Gentaz, E. (2004). Cross-modal recognition of shape from hand to eyes and handedness in human newborns. *Neuropsychologia*, 42, 1365-1369.
- Streri, A., & Milhet, S. (1988). Equivalences intermodales de la forme des objets entre la vision et le toucher chez les bébés de 2 mois (intermodal equivalence of object shape between vision and touch in 2-month-old infants). *L'Année Psychologique*, 88, 329-341.
- Streri, A., & Molina, M. (1993). Visual-tactual and Tactual-visual transfer between objects and pictures in 2-month-old infants. *Perception*, 22, 1299-1318.
- Streri, A., & Pêcheux, M. G. (1986 a). Tactual habituation and discrimination of form in infancy: A comparison with vision. *Child Development*, 57, 100-104.
- Streri, A., & Pêcheux, M. G. (1986b). Vision to touch and touch to vision transfer of form in 5-month-old infants. *British Journal of Developmental Psychology*, 4, 161-167.

-
- Streri, A., & Spelke, E.S. (1988). Haptic perception of objects. *Cognitive Psychology*, 20, 1-23.
- Streri, A., & Spelke, E.S. (1989). Effects of motion and figural goodness on haptic object perception in infancy. *Child Development*, 60, 1111-1125.
- Streri, A., Gentaz, E., Spelke, E.S., & Van de Walle, G. (2004). Haptic perception of object unity in rotating displays. *The Quarterly Journal of Experimental Psychology*, 57, 523-538.
- Streri, A., Lhote, M., & Dutilleul, S. (2000). Haptic perception in newborns. *Developmental Science*, 3, 319-327.
- Streri, A., Spelke, E.S., Rameix, E. (1993). Specific and amodal mechanisms of object perception and exploration in infancy: the case of active touch. *Cognition*, 47, 251-279.
- Tees, R.C. (1994). Early stimulation history, the cortex and intersensory functioning in infrahumans: Space and Time. In D.J. Lewkowicz and R. Lickliter (Eds.). *The development of intersensory perception. Comparative perspectives*. Pp.107-132. Hillsdale: Lawrence Erlbaum Associates.
- Tomasello, M. (1998). Uniquely primate, uniquely human. *Developmental Science*, 1, 1-16.
- Turkewitz, G., Gordon, E. W., & Birch, H. G. (1965). Head turning in the human neonate: spontaneous pattern. *Journal of Genetic Psychology*, 107, 143-158.
- Twitchell, T. E. (1965). The automatic grasping responses of infants, *Neuropsychologia*, 3, 47-259.
- Wynn, K. (1992). Addition and subtraction by human infants. *Nature*, 358, 749-750.

Chapter 14

EMOTIONAL MODULATION OF SELECTIVE ATTENTION: EXPERIMENTAL EVIDENCE IN SPECIFIC PHOBIA

***Marlen Figueroa¹, Sonia Rodríguez-Ruiz¹, José L. Mata^{1,2},
Walter Machado-Pinheiro³ and Jaime Vila¹***

¹University of Granada, Granada, Spain

²University of Jaén, Jaén, Spain

³Federal Fluminense University, Rio de Janeiro, Brazil

1. INTRODUCTION

Empirical research has demonstrated that emotional information is rapidly and extensively processed and that assessment of that information takes place automatically, outside of conscious awareness (Edelstein & Guillath, 2008). This processing bias presumably occurs in conditions that require the healthy or anxious individual to scan the environment for information (Mathews & MacLeod, 1994). So, the attention is captured by, or shifted towards, emotionally relevant stimuli. Multiple factors can explain how emotion drives attention. This chapter throws light on some of these factors.

Emotional Arousal and Survival

From an evolutionary point of view, some authors propose that phylogenetically prepared fear-eliciting stimuli, due to their survival value, drive attention independently of the individual's anxiety level (Lipp & Derakshan, 2005; Öhman et al., 2001).

Similarly, Lang and collaborators (1997) suggest that preferential processing of threatening information is an adaptive response whenever an arousing stimulus appears in the

¹ Departamento de Personalidad, Evaluación y Tratamiento Psicológico Facultad de Psicología Universidad de Granada Campus de la Cartuja s/n 18071, Granada (Spain) Phone: (+ 34) 958 24 37 53 (Lab) (+ 34) 958 24 62 50 (Office) Fax: (+ 34) 958 24 37 49 E-mail: srruiz@ugr.es

environment. Bradley and colleagues (2001, 2003) have examined the behavioral and physiological responses toward emotional images and have found that these emotional responses vary according to the valence and arousal of the images. In fact, Cisler and coworkers (2007) indicate that the difficulty in disengaging oneself from emotional stimuli is explained by their arousal.

The attentional interference in high arousal conditions has also been confirmed in other studies showing delayed response latencies when people are looking at erotic or unpleasant images (Schmuck, 2005). Also Chen and collaborators (2002) found similar attention deployment to specific stimulus contents (i.e. positive and negative words). Therefore, affective influences on attention can be predicted by arousal ratings of affective images.

Hemispheric Asymmetry in Emotional and Attentional Processing

Neuropsychological theories emphasize the relevance of the hemispheric mechanisms underlying the emotional processing. Borod and colleagues (2001) propose two alternative hypotheses:

The *right hemisphere hypothesis*. This hypothesis states that the right hemisphere is specialized in emotions, independently of their affective valence (positive or negative). Therefore, right hemisphere strategies (integrative and holistic) and functions (non-verbal and visio-spatial) are specifically linked to the processing of affective stimuli. In addition, the right hemisphere has a greater multimodal integration capacity (Goldberg & Costa, 1981) and larger connections between lobe and axonal regions than the left hemisphere. According to this hypothesis, the right hemisphere meets all the requirements for processing emotional information.

The *valence hypothesis*. This hypothesis has two versions. The first one proposes that the right hemisphere is specialized in unpleasant and negative emotions whereas the left hemisphere is specialized in pleasant and positive ones, independently of the processing mode (i.e. perception and expression).

The second version claims that the hemispheric specialization occurs for the expression and experience of emotion, but that the right hemisphere is dominant for the perception of emotions of both valences (Davidson, 1984).

So far, the *right hemisphere hypothesis* has received more support (Borod et al., 2001; Mathews & Klug, 1993; Richards et al., 1995; Van Serien & Heijt, 1995, amongst others). In contrast with the large number of studies examining this hypothesis, less research has been done into the *valence hypothesis*.

In line with the latter hypothesis, Mathews and Klug (1993) demonstrated that participants showed a right hemispheric interference only when processing threat-related words. However, those who reported higher trait anxiety levels also showed this interference with positive words. Similarly, and congruent with the *right hemisphere hypothesis*, Richards and coworkers (1995) reported that participants with high anxiety levels show significant interference with emotional contents (both positive and negative ones) presented in the left visual field (right hemisphere) in comparison with neutral content.

Attention, Anxiety and Negative Affect

Although emotional stimuli are processed in a preferential manner over neutral ones in all individuals, people who manifest higher anxiety levels present greater attentional biases during affective processing. The direction of the bias is, however, unclear. Various studies (Buodo et al., 2006; Cisler et al., 2007) confirm that anxious individuals assign more attentional resources to processing threatening information than people without anxiety. Accordingly, it has been suggested that anxious individuals are oversensitive or hypervigilant in detecting danger (*hypervigilance or facilitation hypothesis*) (Beck et al., 1985; Heinrichs et al., 2001). However, other investigations (i.e. Foa & Kozak, 1986) point in the opposite direction, showing that highly anxious individuals tend to inhibit or avoid deep processing of threatening information, which leads them to a “cognitive avoidance” of threat stimuli (*avoidance or inhibition hypothesis*).

Recently, some authors (Mogg, Bradley, Bono & Painter, 1997) have integrated these two hypotheses in a model that suggests that anxious people are hypervigilant toward threatening stimuli in the early stages of information processing, avoiding this information in late stages (*hypervigilance-avoidance theory*) (Amir, Foa & Coles, 1998). Mogg et al. (2004), for example, have shown that anxious people manifest greater engagement toward highly threatening images when presented for short periods, but that they also manifest greater avoidance to these images when they are presented for longer periods.

A possible explanation of the changes in attentional bias regarding emotional stimuli may be found in Posner's (1986) theoretical model of selective attention. Posner's model proposes a series of elemental operations involved in selective attention: 1) interruption of ongoing behavior, 2) disengagement of the attentional focus, and 3) movement and re-engagement of the attentional focus toward a new location.

Within this framework, Posner and collaborators (Posner, Cohen & Rafal, 1982) have developed a signal-target paradigm to study the operations involved in selective visual attention. The procedure consists of asking the participants to press one of two computer keyboard buttons (e.g., “n” or “b”) as quickly as possible when identifying the correct position of the target stimulus (e.g., an asterisk) that appears on the screen to the right or left of the central fixation point (e.g., a cross, where the participants are directing their eyes). The target is normally presented after the appearance of a signal stimulus on the screen (i.e., an arrow pointing toward the position where the target will appear or a lit up triangle in the same place where the target will appear). The signal can be presented either indicating the same visual field where the target will be presented (valid trials) or indicating the opposite visual field (invalid trials). The reaction times (RTs) and the number of errors made when detecting the target are, in general, larger in the invalid trials than in the valid ones. Thus, in the invalid trials an attentional interference occurs, whilst in the valid trials an attentional facilitation takes place. Therefore, the latency in the RTs and the number of incorrect responses (IRs) made when detecting the target in the invalid trials determines the cost of disengagement, movement and re-engagement of selective visual attention toward the target.

There are many versions of this task. One example is the version developed by Stormark and colleagues (1995) who used emotionally negative words (i.e., death, anxiety, murder, illness) and neutral ones (i.e., day, month, hour, week) as signals of the target stimuli, presented in the location where the target was to be shown (valid trials) or in the opposite location (invalid trials). The results of this study demonstrated that control participants had

lower RTs in valid trials and higher RTs in invalid trials when the signal was a negative word than when the signal was a neutral word. These results confirm that (a) emotional signals presented in the same location as the target facilitate the ability to focus attention (engagement), and (b) emotional signals presented in the opposite location as the target increase the cognitive cost of attentional change interfering in the movement of attention (disengagement). The changes of selective attention found in this task have been related to the facilitation effect observed in anxious individuals toward threatening information. For example, Amir and coworkers (2003) have suggested that individuals with social phobia would get engaged on socially threatening stimuli.

Stormark, Field, Hugdahl and Horowitz (1997) have specifically reported data that support the *hypervigilance-avoidance hypothesis* using different intervals of time between the signal and the target (Stimulus Onset Asynchrony [SOA]) to evaluate the influence of emotionally relevant words in participants with alcoholism (i.e. beer, bar, vodka, liquor bar). The results of this study provide evidence that people with alcoholism show higher RTs for targets invalidly signaled by alcohol words than for targets invalidly signaled by neutral words when the signal-target interval was short (SOA= 100 ms). This result suggests an increased difficulty to disengage attention from affective stimuli at a preattentive or automatic level (hypervigilance). However, the same people showed the opposite effect -lower RTs for targets invalidly signaled by alcohol words than for targets invalidly signaled by neutral words- when the signal-target interval was long (SOA= 500 ms). This result suggests an increase facilitation to disengage attention from affective stimuli at a non-automatic or controlled level (avoidance).

Other studies have reported similar effects. Vassilopoulos (2005), in a study with social phobics, concluded that high levels of anxiety provoked both hypervigilance for threatening signals in short presentations and avoidance of the same stimuli in long presentations. Mogg and Bradley (2002) have defended similar conclusions.

Koster and collaborators (2005) have conducted two studies to examine if negative mood or dysphoria also produces attentional bias. Differing from the previous findings, their results reveal that participants with negative mood keep their attention on negative words presented during long intervals (SOA= 1500 ms), which is probably caused by difficulty in disengaging their attention from those words. Healthy participants, on the contrary, kept their attention focused on positive words. These data support the existence of mood-congruent attentional bias in dysphoria. Thus, positive mood eases the processing of positive information and negative mood the processing of negative information. However, this effect occurs in the later and not the earlier stages of information processing.

As regards the difficulty in disengaging attention from threatening stimuli, Koster and colleagues (2004) point out the existing confusion concerning whether anxious individuals (a) are hypervigilant and engaged on threatening information, or (b) have difficulty in disengaging from that information. Based on their results, they conclude in favour of the second option. The same conclusion would be applicable for people with negative mood, dysphoria or depression.

Vassilopoulos (2005) studied socially anxious participants to determine if the differences observed amongst participants with high and low social anxiety were due to individual differences in propensity to anxiety or due to general differences in negative affectivity. Given their results, the author suggests that participants with high depression or negative affect show greater avoidance of threatening words, whereas those with high trait anxiety

show higher avoidance of socially negative words but higher vigilance toward socially positive ones.

Emotional Processing and Motivated Attention

Another possible explanation of why emotional information influences attentional behavior is offered by motivational models of emotion (Lang, 1995; Lang, Davis & Öhman, 2000). Under this framework, emotions are considered action dispositions intimately linked to two basic motivational systems, one appetitive and the other defensive. The appetitive system is activated in contexts that promote sustenance and procreation, whereas the defensive system is activated in contexts involving danger and threat. Attention is considered an adaptive process, intimately related to these motivational systems, and absolutely necessary for the organism's survival. Attentional resources are primarily allocated to situations motivationally relevant for the organism. This type of attention is called "motivated attention" (Bradley, Cuthbert & Lang, 1999). An example of how motivation drives attention is seen in the *cascade model of defensive reactions*. This model assumes that, in natural settings, defensive reactions follow a sequence or cascade of responses from attention to response mobilization as a function of proximity of the danger and the arousal level. The initial phase of the sequence is characterized by the *freezing* response, a state of attentive immobility when the danger is first encountered at a safe distance and the arousal level is low. The sequence changes into active defense, either *flight* or *fight*, when the danger is approaching and the arousal level is high.

Consistent with this model, several investigators have suggested that when people observe highly arousing negative images, they activate the defensive system producing a *freezing*-like reaction (Azevedo et al., 2005). Fox and collaborators (2007) have proposed that the *freezing* reaction found in animals could survive in humans at a more subtle level being revealed in greater response latencies during tasks that involve presentation of fear-relevant stimuli, specially in individuals with high anxiety levels.

Garcia Pereira and colleagues (2006) also suggest that the presentation of positive and negative emotional images activates the two motivational systems prompting approach/avoidance behavioral tendencies. Therefore, viewing pleasant and unpleasant images should activate the appetitive and the defensive system, respectively, favouring motor actions congruent with the activated system (approach or avoidance).

Duckworth and coworkers (2002) measured the reaction time to the detection of positive and negative images and words under two response conditions: pulling a lever (approach) or pushing the lever (avoidance). Participants were faster at pulling the lever to detect the positive stimuli than detecting the negative ones. On the contrary, they were faster at pushing the lever to detect the negative stimuli than detecting the positive ones. Therefore, the reaction time was facilitated when there was congruence between the type of stimulus (positive/negative) and the type of response (approach/avoidance). Incongruence produced the opposite effect.

Similarly, Wentura and collaborators (2000) instructed participants to withdraw the finger from a key (avoidance condition) or to press the key (approach condition) in response to the presentation of affective words in a Go/No-Go task. It was found that responses to the negative words were faster in the avoidance condition whereas responses to the positive

words were faster in the approach condition. Congruence between the motivational system activated by the stimuli (appetitive/defensive) and the type of response (approach/avoidance) was the key factor to produce improved reaction times.

Within this perspective, the delayed reaction times, observed when unpleasant stimuli are presented in paradigms that request pressing a key, could be explained as being due to incongruence between the type of response requested (approach) and the motivational system activated by the stimuli (the defensive one).

The goal of the present investigation was to examine the attentional bias toward significant stimuli in a group of people with intense specific fears (subclinical phobics), compared to a control group, using a modified version of Posner's signal-target attentional task (Posner, Cohen & Rafal, 1982). Participants were tested for attentional biases toward phobic/non-phobic images and toward standard pleasant, neutral and unpleasant images. Within this general goal, the investigation addressed three major topics: the laterality, the stimulus onset asynchrony, and the negative affectivity effect. The three topics will be analyzed separately following a sequential subdivision of the results into three parts. Specific hypotheses for each part will be presented after description of the method.

2. METHOD

2.1. Participants

The participants were 77 students and staff from the University of Granada who displayed either an intense fear toward a specific potentially phobic stimulus but no fear toward another potentially phobic stimulus (experimental group: 36 women and 4 men) or no fear toward any of both stimuli (control group: 33 women and 4 men). The participants' ages in the experimental group were between 18 and 27 years old ($M = 23.52$; $SD = 4.97$) and those of the control group were between 18 and 39 years old ($M = 22.84$; $SD = 4.14$). The experimental and control groups were selected in accordance with the results of the abbreviated ADIS-IV interview schedule (Brown, Di Nardo, & Barlow, 1994). Fearful participants had intense fear, at least, of one specific phobic stimulus (score higher than 6), but no fear, at least, of another specific phobic stimulus (score lower than 3), within a list of potentially phobic stimuli. Control participants were people with no intense fears of any of the phobic stimuli in the list (scores lower than 6), and with no fear of any of the two stimuli (phobic and non-phobic) to be presented and previously selected by an experimental participant. None of the participants had any anxiety disorder or was undergoing pharmacological or psychological treatment. None displayed auditory and/or visual deficiencies or any other physical problem. They participated voluntarily in the investigation.

2.2. Design

We used a mixed factorial design with one between-group factor (the Experimental and Control groups) and four within-subject factors corresponding to four manipulations of the attentional task: Laterality of the target (Valid versus Invalid trials), Stimulus Onset

Asynchrony (Short versus Long SOA interval), Visual field Presentation (Right versus Left visual field), and Type of Affective Image (Pleasant, Neutral, Unpleasant, Phobic and Non phobic).

2.3a. Attentional Task

The attentional task was a modified version of Posner's signal-target attentional task. The signal stimuli were the affective images presented in the right or left visual field of the screen and the target stimulus was an asterisk (*) presented on the same or opposite location of the signal stimulus. Participants were instructed that the images preceding the target would predict in two thirds of the trials the correct location where the target would be presented (valid trials). In the remaining trials, the images would be non-predictive (invalid trials). Participants had to press one of two keys as quickly and accurately as possible to indicate if the target appeared on the right or left visual field. The task included one practice block of 36 trials and five experimental blocks of 60 trials ($5 \times 60 = 300$ trials). Each trial had the following sequence:

1. Presentation of the fixation point (+) in the center of the computer screen for a randomized variable time of 550, 600, 650, 700, 750 or 800 ms.
2. Presentation of the affective image to the right or left side of the fixation point (occupying 25% of each half of the computer screen) for a time period of either 100 ms or 800 ms.
3. Presentation of the target stimulus (*) to the right or left side of the fixation point for a time period of 2 seconds.
4. Subject's response during this period pressing the "n" or "b" key depending on whether the target appeared on the right ("n") or left ("b") side of the fixation point.
5. A randomized inter-trial interval of 900, 940, 980, 1020, 1060 or 1100 ms duration..

In the practice block, all images were neutral. In the experimental blocks, affective images were phobic, non-phobic, pleasant, neutral and unpleasant presented in random order. Within each experimental block, there were 40 valid trials (8 trials per affective category) and 20 invalid trials (4 trials per affective category). Within each type of trial (valid or invalid) and affective category there were equal number of trials with 100 ms or 800 ms SOA, and presented in the right or left visual field (see Table 1).

2.3b. Affective Images

The pleasant, neutral and unpleasant images were selected from the International Affective Image System [IAPS] (Lang et al., 1999). Twelve images of each category were used. The pleasant and unpleasant images were matched in arousal level. The rest of the images (12 phobic and 12 non-phobic ones) were selected from a phobic image library taken from the Internet (Viedma et al., 2008). These images were specific for each fearful and non-fearful participant and included spiders, snakes, dogs, cats, cockroaches, wasps, pigeons,

heights, darkness, deep water, bats, and injections-blood. All images were presented with a 646 x 699 pixels resolution and were centered on a black 1024 x 768 sheet.

Table 1. Experimental block design

40 Valid trials (VT)	8 VT with Pleasant images (P)	4 VT (P) SOA 100	2 VT (P) 100 Right
			2 VT (P) 100 Left
		4 VT(P) SOA 800	2 VT (P) 800 Right
			2 VT (P) 800 Left
	8 VT with Neutral images (N)	4 VT (N) SOA 100	2 VT (N) 100 Right
			2 VT (N) 100 Left
		4 VT (N) SOA 800	2 VT (N) 800 Right
			2 VT (N) 800 Left
	8 VT with Unpleasant images (U)	4 VT (U) SOA 100	2 VT (U) 100 Right
			2 VT (U) 100 Left
		4 VT (U) SOA 800	2 VT (U) 800 Right
			2 VT (U) 800 Left
	8 VT with phobic images (Ph)	4 VT (Ph) SOA 100	2 VT (Ph) 100 Right
			2 VT (Ph) 100 Left
		4 VT (Ph) SOA 800	2 VT (Ph) 800 Right
			2 VT (Ph) 800 Left
	8 VT with Non Phobic images (NPh)	4 VT (NPh) SOA 100	2 VT (NPh) 100 Right
			2 VT (NPh) 100 Left
		4 VT (NPh) SOA 800	2 VT (NPh) 800 Right
			2 VT (NPh) 800 Left
20 Invalid trials (IT)	4 IT with Pleasant Images (P)	2 IT (P) SOA 100	1 VT (P) 100 Right
			1 VT (P) 100 Left
		2 IT (P) SOA 800	1 VT (P) 800 Right
			1 VT (P) 800 Left
	4 IT with Neutral Images (N)	2 IT (N) SOA 100	1 VT (N) 100 Right
			1 VT (N) 100 Left
		2 IT (N) SOA 800	1 VT (N) 800 Right
			1 VT (N) 800 Left
	4 IT with Unpleasant Images (U)	2 IT (U) SOA 100	1 VT (U) 100 Right
			1 VT (U) 100 Left
		2 IT (U) SOA 800	1 VT (U) 800 Right
			1 VT (U) 800 Left
	4 IT with Phobic Images (Ph)	2 IT (Ph) SOA 100	1 VT (Ph) 100 Right
			1 VT (Ph) 100 Left
		2 IT (Ph) SOA 800	1 VT (Ph) 800 Right
			1 VT (Ph) 800 Left
	4 IT Non phobic Images (NPh)	2 IT (NPh) SOA 100	1 VT (NPh) 100 Right
			1 VT (NPh) 100 Left
		2 IT (NPh) SOA 800	1 VT (NPh) 800 Right
			1 VT (NPh) 800 Left

2.3c. Subjective Assessment of Phobic/Non-Phobic Images

The subjective assessment of 8 phobic and 8 non-phobic images (those used in the last block of the attentional task) was undergone by participants, after completing the attentional task, using the 4 scales of the Self-Assessment Manikin (see below) and following the same procedure applied in the elaboration of the Spanish norms of the International Affective Picture System (Moltó et al., 1999; Vila et al., 2001). The participants, after receiving the

instructions, practiced the assessment of 3 neutral images. Following that, they assessed the 16 affective images presented in random order. The images stayed projected, occupying 100% of the computer screen, for 6 seconds. Immediately after the presentation of each image, the Valence, Arousal, Dominance, and Attention scales were projected on the screen, in that order, and the participants made their ratings on the screen using the computer mouse.

2.4. Apparatus and Instruments

The attentional task and the subjective assessment of the images were controlled by a Pentium IV computer running on *Windows XP* and the *E-prime software*. This software provides a standardized programming language common to psychological research. In this study, it was used to obtain: (a) the randomized presentation of the visual stimuli and (b) the recording of the participant's responses (Reaction Times, Incorrect Responses, and Subjective Ratings).

2.5. Dependent Variables

2.5.1. Behavioral Measures

Reaction time (RT): Latency time in milliseconds to detect the presentation of the target at the correct location. In this investigation, the median of the RTs for each type of trial is used as the dependent variable.

Incorrect responses (IR): Frequency of errors in pressing the correct key after the presentation of the target. In the present work, the average IR for each type of trial is used as the dependent variable.

2.5.2. Self-Report Measures

Self-Assessment Manikin [SAM] (Lang, 1980). The SAM consists of human-like figures that embody the dimensions of valence, arousal, and dominance, with five figures representing nine (1-9) intensity levels within each dimension. SAM's valence rating ranges from a figure with a large smile to a figure with a pronounced frown, arousal rating ranges from a figure that appears agitated to a figure that looks drowsy, and the dominance-submissiveness rating ranges from a very large figure to a very small figure. Recently, a fourth dimension, labelled 'attention', has been included (Joffily, Jandre & Volchan, 2005). Attention ratings range from a figure outwardly oriented (alert) to a figure inwardly oriented (thoughtful). This assessment method has been extensively used in emotional research (e.g., Bradley & Lang, 1994).

Positive and Negative Affect Schedule [PANAS] (Watson, Clark & Tellegen, 1988). This questionnaire measures two dimensions of affectivity (positive and negative) either as trait or state. It contains 20 adjectives (10 for each dimension) with a scoring format from 1 ("not at all") to 5 ("extremely"). The PANAS is said to possess excellent psychometric properties with Northamerican and Spanish samples (Lostao et al., 1999; Robles & Páez, 2003).

STAIT Anxiety Inventory [STAI] (Spielberger, Gorsuch, & Lushene, 1970). This questionnaire measures the level of anxiety a person experiences. It includes a state version

[STAI-S] and a trait version [STAI-T]. The instrument comprises 20 items for each version with a scoring format from 0 (“Hardly ever”) to 3 (“Nearly always”) for each item.

Anxiety Disorder Interview Schedule for DSM-IV [ADIS-IV] (Brown, Di Nardo, & Barlow, 1994). This semistructured interview was used for the selection of the participants. The ADIS- IV is a diagnostic instrument for clinical assessment of anxiety disorders, with sound psychometric properties (Brown et al., 1994). It follows the DSM-IV diagnostic criteria. In our study, it was used to confirm absence of any formal anxiety disorder in all participants, except for intense fear of specific objects and situations (sub-clinical phobia) in participants belonging to the experimental group.

2.6. Procedure

Participants were first contacted informally by announcements in classes and personal communication. They then attended a laboratory session divided into three phases. In the first one, the participant was informed of the general aim of the study, signed the informed consent form, and completed the ADIS-IV, the PANAS-Trait, and the STAI-Trait. At the end of this phase, participants were classified as experimental, control, or neither experimental or control. Experimental participants were matched with control participants in such a way as to have, as a whole, the same phobic and no-phobic stimuli in both groups. People not complying with the inclusion criteria did not participate in the following phases of the study. In the second phase, participants performed the attentional task and the subjective assessment of the phobic/non-phobic images in this order. During both tasks, the researcher stayed in an adjacent room to the experimental one. On completion of the attentional task, the researcher went into the participant's room to give instructions on how to assess the images using the SAM scales. In the final phase, participants completed the PANAS-State and STAI-State questionnaires, were thanked for their collaboration, and received a certificate that accredited their voluntary participation in the study.

2.7. Data Analysis

The SPSS 15 for Windows statistical package was used for all analyses. One-way ANOVA tests (for self-report measures) and mixed-factorial ANOVAs (for behavioral measures) were conducted. These ANOVAs used specific combinations of the repeated measure factors in order to facilitate the analysis and presentation of the results into three sub-analyses: a) Sub-analysis 1: focused on standard Affective Images (Pleasant, Neutral and Unpleasant) and Visual Field Presentation (Left and Right); Sub-analysis 2: focused on Phobic Images (Phobic and Non-Phobic), Laterality (Valid and Invalid), and SOA (100 and 800 ms); and Sub-analysis 3: focused on individual differences in Negative Affectivity. All analyses considered possible violation of the assumption of error variance homogeneity, and the Greenhouse-Geisser correction was applied to repeated measure factors. Results are reported with the original degrees of freedom and the corrected probability values. In the analyses of significant interactions, pairwise comparisons were performed using t-test. The level of significance was set at 0.05 for all analyses.

3. SPECIFIC AIMS AND RESULTS

3.1. Sub-Analysis 1: Modulation of Attention by Standard Affective Images and Visual Field Presentation

A large research literature (Borod et al., 2001; Edelstein & Guillaith, 2008; Lipp & Derakshan, 2005; Mathews & Klug, 1993; Mathews & MacLeod, 1994; Öhman et al., 2001; Richards et al., 1995, amongst others) has confirmed the adaptive tendency to favor attentional processing of emotional information as well as the dominance of the right hemisphere in attentional tasks. Hence, in this first sub-analysis, we intended to examine the emotional modulation of attention toward standard affective images (pleasant, neutral and unpleasant) regarding the right and left visual field in sub-clinical phobic and control participants. Given the non specific character of the standard affective images, we expect to find increased RTs and an increased number of IRs in all participants in trials where pleasant and unpleasant images are presented, compared to neutral ones (arousal effect). Also, we expect to find increased RTs and an increased number of IRs for all participants in trials where the standard affective image is presented in the left visual field compared to trials where the affective image is presented in the right visual field.

3.1.1. Reaction Time

The 2(x3x2) ANOVA with one between-group factor, *Group* (with 2 levels: Experimental and Control) and two repeated measure factors: *Image* (with 3 levels: Pleasant, Neutral and Unpleasant) and *Visual Field Presentation* (with 2 levels: Right and Left) showed significant main effects of *Image* ($F(2,152)=7.117$, $p<0.01$) and *Visual Field Presentation* ($F(1,76)=17.997$, $p<0.001$). The *Group* factor and the interactions were not significant. The significant effect of *Image* reflects the longer RTs to respond to the target in trials where pleasant and unpleasant images are presented, in that order, compared to neutral ones (see Figure 1.1). The significant effect of *Visual Field Presentation* reflects the longer RTs to respond to the target in trials where the affective images are presented in the left visual field compared to those presented in the right visual field (Right: $M=399$ ms; Left: $M=413$ ms).

3.1.2. Incorrect Responses

The 2(x3x2) ANOVA showed a significant main effect of *Visual Field Presentation* ($F(1,76)=4.000$, $p<0.05$). Participants, irrespective of the Group, made more mistakes when responding to the target in trials where the affective images were presented in the left visual field than in the right visual field (Right: $M=0.190$; Left: $M=0.329$).

The *Image* factor was not significant, although the tendency replicates the RTs results: Participants, irrespective of the Group, made more mistakes in trials where pleasant and unpleasant images are presented, in compared to neutral ones (see Figure 1.2).

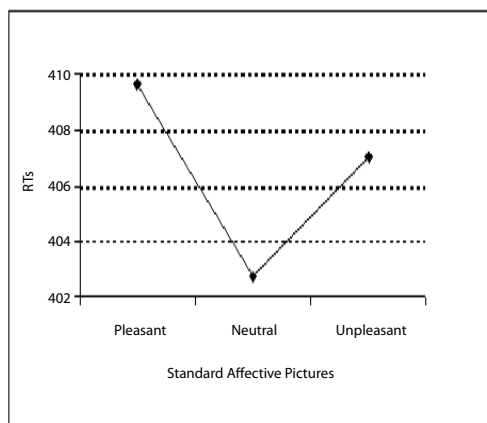


Figure 1.1. Average RT after pleasant, neutral and unpleasant image presentation.

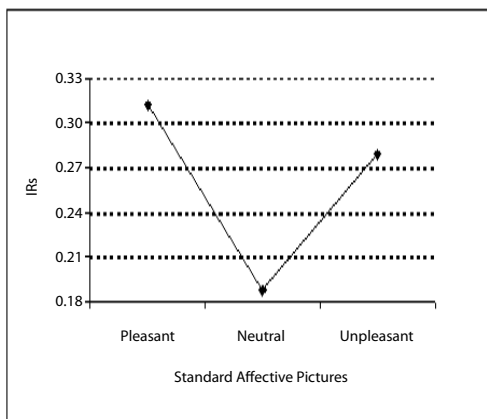


Figure 1.2. Average number of IRs after pleasant, neutral and unpleasant image presentation.

3.2. Sub-Analysis 2: Modulation of Attention by Phobic Images, Laterality and Soa

According to the vigilance-avoidance hypothesis (Amir, Foa & Coles, 1998; Mogg, Bradley, Bono & Painter, 1997; Mogg et al., 2004), phobic stimuli with high negative valence and arousal should modulate the performance of anxious people in an attentional task showing interference or facilitation depending on the stage of the information processing (Buodo et al., 2006; Cisler et al., 2007; Lang et al., 1997; Schimmack, 2005). In early stages (short presentations), anxious people would show greater engagement to phobic images (hypervigilance), whereas in later stages (long presentations), they would show greater disengagement (avoidance). Engagement and disengagement would be indexed by interference versus facilitation in our attentional task. Therefore, in this sub-analysis we intend to examine: (a) the asynchrony effect between the affective images and the target

presentation in Short and Long SOA trials, and (b) the influence of the spatial location in Valid and Invalid trials.

We expect to find, in anxious participants, increased RTs and an increased number of IRs in trials where phobic images are presented, compared to non-phobic ones, and compared to control participants. As regards SOA and Laterality we expect increased RTs and an increased number of IRs in Short SOA trials and in Valid trials. Finally, subjective measures (SAM, STAI-S and PANAS-S) should confirm the selection criteria: Participants in the experimental group should assess the phobic images as more unpleasant, more activating, with less control and with more external attention than control participants. They should also score higher in anxiety (STAI-S) and negative affect (PANAS-S).

3.2.1. Reaction Time

The 2(x2x2x2) ANOVA with one between-group factor, *Group* (with 2 levels: Experimental and Control), and three repeated measure factors: *Laterality* (with 2 levels: Valid and Invalid), *Image* (with 2 levels: Phobic and Non-Phobic), and *SOA* (with 2 levels: Short and Long) showed significant main effects of *Image* ($F(1,75)=4.063$, $p<0.05$), *Laterality* ($F(1,75)=11.318$, $p<0.001$), and *SOA* ($F(1,75)=133.239$, $p<0.001$), and an interaction effect of *Laterality* x *SOA* ($F(1,73)=11.908$, $p<0.001$).

The significant *Image* effect is similar to the effect described in 3.1.1 (see Fig. 2.1): longer RTs in trials where phobic images are presented, compared to non-phobic ones. As expected, these differences are larger for experimental than control participants. The significant *SOA* effect indicates longer RTs in trials with 100 ms SOA than in trials with 800 ms SOA. The significant *Laterality* effect indicates longer RTs in Invalid than in Valid trials and *Laterality*), the direction of the changes is the same as indicated above.

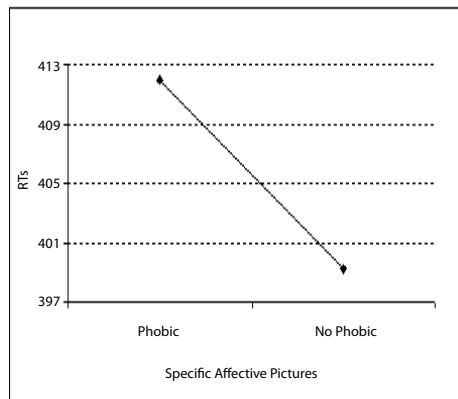


Figure 2.1. Average RT after phobic and non-phobic image presentation.

However, the above effects should be considered taking into account the significant *Laterality* x *SOA* interaction. This interaction is analyzed below taking into consideration also the *Group* and *Image* factors. When the main effects are again found, in this interaction analysis, at the different levels of each factor (*SOA*

A. SOA EFFECT IN VALID AND INVALID TRIALS

Valid Trials: There was a significant main SOA effect ($F(1,75)=51.974$, $p<0.001$) and a significant *Image* $\times$ *Group* interaction ($F(1,75)=3.889$, $p<0.05$). The significant interaction indicates that only the experimental group had longer RTs in valid trials where phobic images are presented. The differences were not significant in control participants (see Fig. 2.2).

Invalid Trials: The results indicated significant *Image* ($F(1,75)=3.890$, $p<0.05$) and SOA ($F(1,75)=102.665$, $p<0.001$) effects.

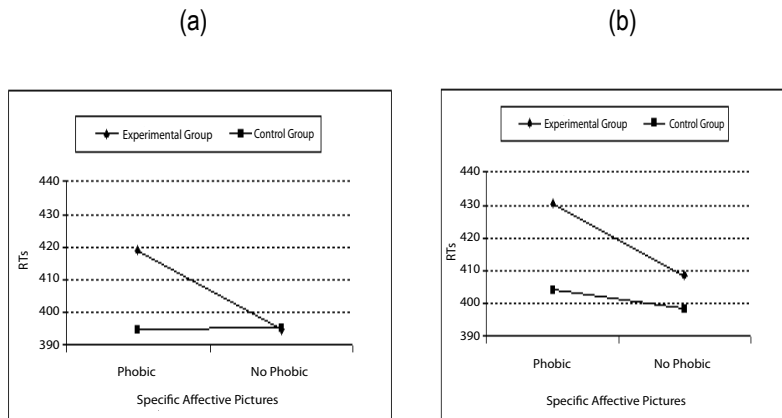


Figure 2.2. Average RT after phobic and non-phobic image presentation for each group in Valid (a) and Invalid (b) trials.

B. LATERALITY EFFECT IN TRIALS WITH SHORT AND LONG SOA

Short SOA trials: There were significant main effects of *Image* ($F(1,75)=4.615$, $p<0.05$) and *Laterality* ($F(1,75)=22.817$, $p<0.001$), and significant interaction effects of *Image* $\times$ *Group* ($F(1,75)=4.095$, $p<0.05$) and *Laterality* $\times$ *Group* ($F(1,75)=3.909$, $p<0.05$). The significant *Image* $\times$ *Group* interaction indicates that only the experimental group had longer RTs in short SOA trials where phobic images are presented. The differences were not significant in control participants (see Figure 2.3).

Long SOA trials: No significant effects were found in any of the main factors (*Image*, *Laterality* and *Group*) and interactions.

3.2.2. Incorrect Responses

The $2(x2 \times 2 \times 2)$ ANOVA, *Group* (with 2 levels: Experimental and Control), *Laterality* (with 2 levels: Valid and Invalid), *Image* (with 2 levels: Phobic and Non-Phobic), and *SOA* (with 2 levels: Short and Long) showed a significant main effect of *Group* ($F(1,75)=5.483$, $p<0.05$) and two significant interaction effects, *Image* $\times$ *SOA* ($F(1,75)=5.209$, $p<0.05$) and *Laterality* $\times$ *SOA* ($F(1,75)=11.605$, $p<0.001$). The significant *Group* effect indicates that the experimental group, in general, made more errors than the control group (see Fig. 2.4). This graph also shows the tendency for all participants to make more errors in trials where the phobic stimulus is presented.

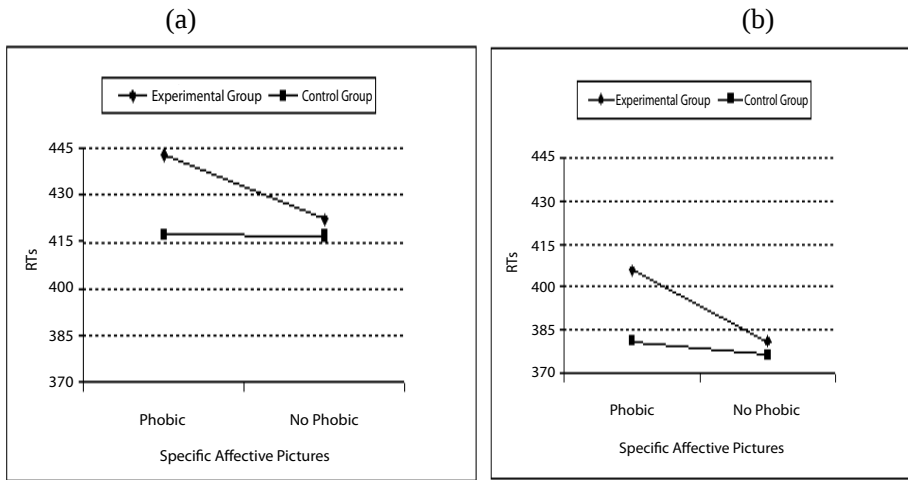


Figure 2.3. Average RT after phobic and non-phobic image presentation for each group in Short (a) and Long (b) SOA trials.

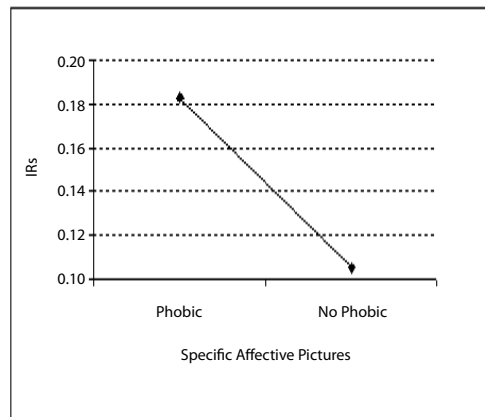


Figure 2.4. Average of number IRs after phobic and non-phobic image presentation.

As regards the *Image* $\times$ *SOA* interaction, the tendency to make more errors in trials where the phobic stimulus is presented becomes significant at long SOA interval (800 ms). At short SOA interval (100 ms), the difference between phobic and non-phobic trials is not significant. On the other hand, the significant *Laterality* $\times$ *SOA* interaction indicates that all participants made more errors in invalid trials than in valid trials, but only at short SOA interval (100 ms). At long SOA interval (800 ms) the differences between valid and invalid trials were not significant.

The following analyses focus on the significant *Laterality* $\times$ *Soa* interaction also taking into account the *Group* and *Image* factors.

SOA EFFECT IN VALID AND INVALID TRIALS

Valid Trials: There were significant main effects of *Group* $F(1,75)=3.773$, $p=0.05$), and *Image* $F(1,75)=3.773$, $p=0.05$), and significant interaction effects of *Image* $\times$ *Group* $F(1,75)=3.889$, $p=0.05$) and *Image* $\times$ *SOA* $F(1,75)=3.773$, $p=0.05$). The experimental group committed more errors in valid trials where the phobic image was presented than in valid trials where the non-phobic image was presented. No such differences were found in the control group (see Fig. 2.5).

Invalid Trials: The results only showed a significant main effect of *Group* $F(1,75)=6.045$, $p<0.05$).

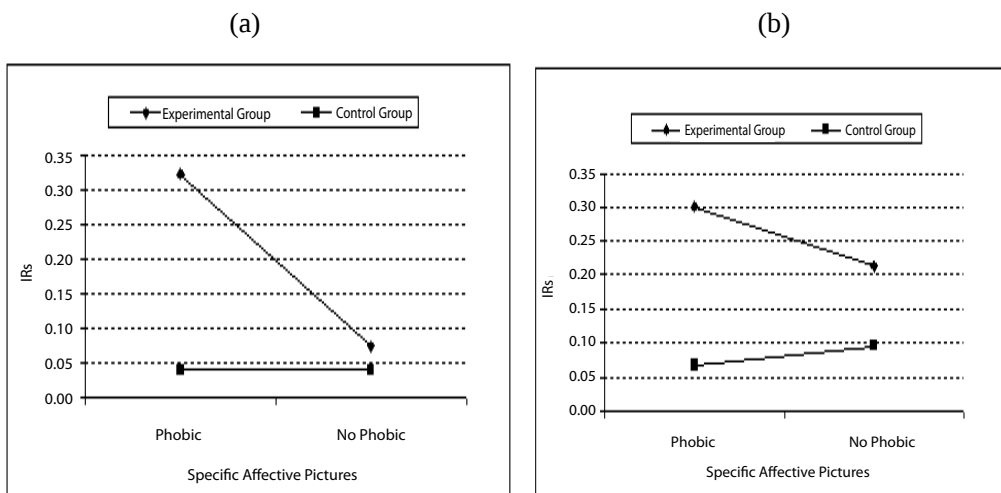


Figure 2.5. Average number of IRs after phobic and non-phobic image presentation for each group in Valid (a) and Invalid (b) trials.

3.2.3 Subjective Measures

Participants in the experimental group significantly reported more negative affect (PANAS-E, $F(1, 75)=11.150$, $p<0.001$) and more anxiety (STAI-E, $F(1, 75)=18.784$, $p<0.000$) after the experiment than control participants (see Table 2.1). They also assessed the phobic images as significantly more unpleasant ($t(75)=14.175$, $p<0.001$), more arousing ($t(75)=9.488$, $p<0.001$), less controllable ($t(75)=9.862$, $p<0.001$), and eliciting higher external attention ($t(75)=6.130$, $p<0.001$) than control participants. They also assessed the non-phobic images as significantly more pleasant ($t(75)=3.195$, $p<0.01$), less arousing ($t(75)=3.308$, $p<0.001$), and more controllable ($t(75)=2.872$, $p<0.01$) than control participants (see Table 2.2).

3.3. Sub-Analysis 3: Modulation of Attention by Trait Anxiety and Negative Affect

Previous studies have supported the existence of an attentional bias in people that inform of high levels of anxiety and negative affect (Compton, 2000; Harman et al., 1997; Koster et

al., 2005; Vassilopoulos, 2005). The aim of our final sub-analysis is to examine whether the combination of anxiety and high negative affect maximizes the attentional bias found in our previous analysis (sub-analysis 2). We expect to find that participants with intense fears of phobic stimuli and high levels of negative affect would show higher indices of attentional bias (RTs and IRs) and higher indices of negative reaction to the phobic images. For this analysis, the experimental and control groups were divided into two groups -high and low in negative affect- according to their score in the PANAS-T scale.

Table 2.1. Mean and standard deviation of PANAS-S and STAI-S scores for each group

	PANAS-S (Negative)		PANAS-S (Positive)		STAI-S	
	Mean	SD	Mean	SD	Mean	SD
Experimental Group	10.25	6.323	16.925	5.775	21.900	9.828
Control Group	5.757	5.402	19.810	7.717	13.729	6.136
Experimental Group	10.250	6.323	16.925	5.775	21.900	9.828
Control Group	5.757	5.402	19.810	7.717	13.729	6.136

Table 2.2. Mean (and standard deviation) SAM scores after phobic and non-phobic images presentation for each group

	Valence		Arousal		Dominance		Attention	
	Phobic	Non-Phobic	Phobic	Non-Phobic	Phobic	Non-Phobic	Phobic	Non-Phobic
Experimental Group	1.80 (1.07)	7.57 (1.17)	7.98 (1.20)	3.24 (1.69)	2.28 (1.34)	6.31 (1.59)	7.48 (1.69)	4.42 (1.53)
Control Group	5.20 (1.03)	6.60 (1.47)	5.12 (1.44)	4.46 (1.53)	5.04 (1.09)	5.46 (0.89)	5.54 (0.96)	4.66 (1.25)

3.3.1 Reaction Time

The analyses presented in this sub-study followed a mixed-factorial ANOVA using 2x2(x2x2x2) repeated measures, with *Group* (with 2 levels: Experimental and Control) and *Negative Affect* (with 2 levels: High and Low), as between-group factors, and three repeated measure factors: *Laterality* (with 2 levels: Valid and Invalid), *Image* (with 2 levels: Phobic and Non-Phobic), and *SOA* (with 2 levels: Short and Long).

The results showed statistically significant effects of *Image* ($F(1,73)=4.889$, $p<0.05$), *Laterality* ($F(1,73)=10.979$, $p<0.001$), *SOA* ($F(1,75)=140.694$, $p<0.001$), *Negative affect* ($F(1,73)=7.406$, $p<0.008$), and in *Laterality x SOA* ($F(1,73)=11.544$, $p<0.001$), *SOA x Group x Negative Affect* ($F(1,73)=5.946$, $p<0.017$) and *Image x Group x Negative Affect* ($F(1,73)=3.752$, $p<0.057$) interactions.

The significant main effect of *Negative Affect* indicates that the group with high negative affect had longer RTs in general. However, the *Image x Group x Negative Affect* interaction indicates that only the experimental group with high negative affect had delayed responses in

trials where the phobic images were presented compared to non-phobic ones. No such differences were found in the experimental group with low negative affect or in the control group with high and low negative affect (see Figure 3.1).

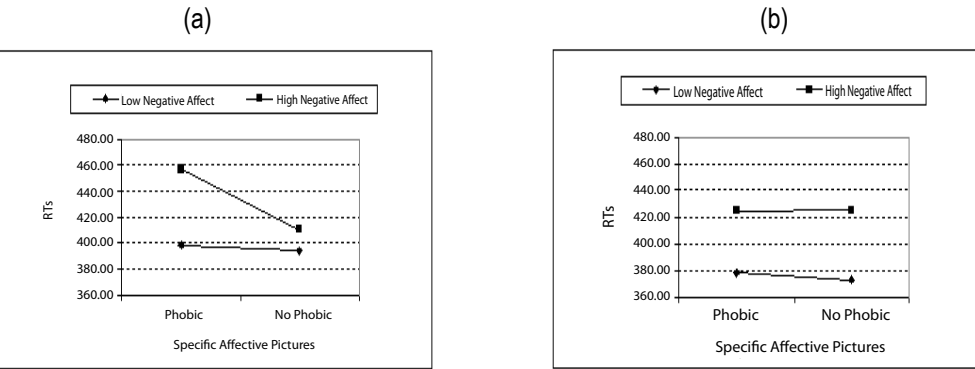


Figure 3.1. Average RT after phobic and non-phobic image presentation for Experimental (a) and Control (b) group regarding Low and High negative affect.

To follow this triple interaction further, we performed an analysis including only the two extreme groups of the *Group x Negative Affect* interaction (the group with high negative affect from the experimental group and the low negative affect from the control group) for the valid and invalid trials separately. The results of this analysis showed that only in valid trials the experimental group with high negative affect had longer RTs than the control group with low negative affect ($t(36)=2.015$, $p<0.05$) (see Fig. 3.2). In invalid trials the differences were not significant.

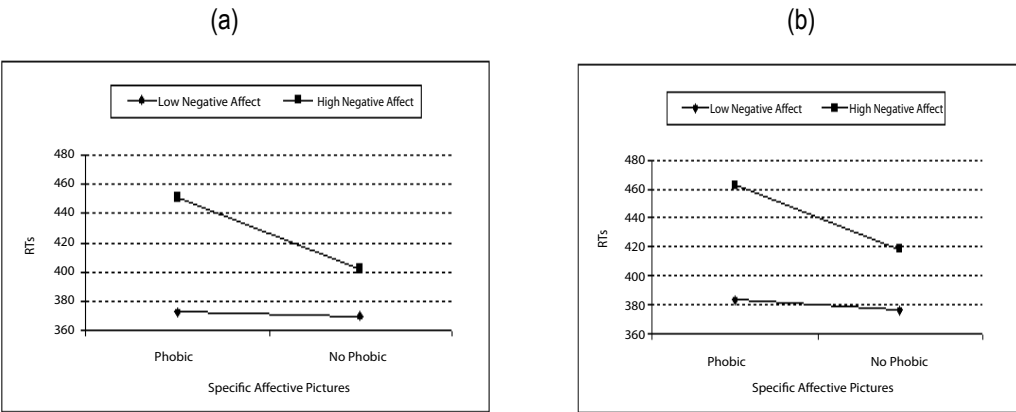


Figure 3.2. Average RT after phobic and non-phobic image presentation for each group in Valid (a) and Invalid (b) trials.

Finally, a similar analysis with only the extreme groups was performed for Short and Long SOA trials separately. The results showed that only in Short SOA trials the experimental group with high negative affect had longer RTs in trials where the phobic image was presented, compared the non-phobic one ($t(36)=2.534$, $p<0.05$) (see Fig. 3.3). No such differences were found in the control group.

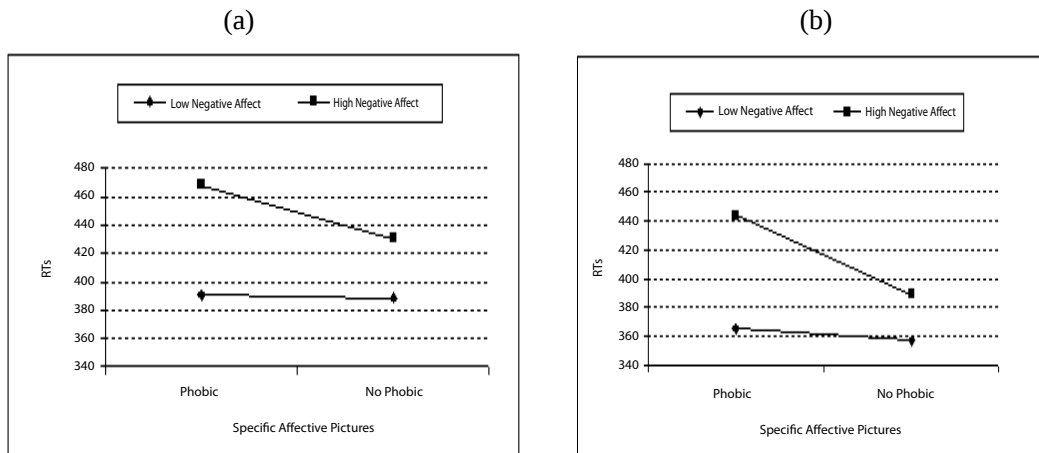


Figure 3.3. Average RT after phobic and non-phobic image presentation for each group in Short (a) and Long (b) SOA trials.

3.3.2 Incorrect Responses

The $2 \times 2 (x2 \times 2 \times 2)$ ANOVA, with *Group* (2 levels: Experimental and Control) and *Negative Affect* (with 2 levels: High and Low), as between-group factors, and three repeated measure factors: *Laterality* (with 2 levels: Valid and Invalid), *Image* (with 2 levels: Phobic and Non-Phobic), and *SOA* (with 2 levels: Short and Long), showed significant effects of *Group* ($F(1,73)=5.935$, $p<0.05$), *Laterality* $\times$ *SOA* ($F(1,73)=13.105$, $p<0.001$), *Laterality* $\times$ *Negative Affect* ($F(1,73)=6.470$, $p<0.01$), *SOA* $\times$ *Image* ($F(1,73)=5.884$, $p<0.01$), *Laterality* $\times$ *SOA* $\times$ *Image* ($F(1,73)=4.186$, $p<0.05$), *Image* $\times$ *Negative Affect* ($F(1,73)=4.661$, $p<0.05$), and *Image* $\times$ *Group* $\times$ *Negative Affect* ($F(1,73)=3.817$, $p<0.05$).

The significant *Image* $\times$ *Group* $\times$ *Negative Affect* interaction indicates that high negative affect participants from the experimental group made more errors in trials where the phobic image was presented than in trials where the non-phobic image was presented.

These differences were not observed in low negative affect participants from the experimental group or high and low negative affect participants from the control group (see Figure 3.4).

The remaining effects concerning *Laterality* and *SOA* were identical to those reported in the previous sub-analysis.

Finally, given the differences observed for experimental and control groups with high and low negative affect, we performed similar analyses to those performed for RTs using the extreme groups (Experimental group with High Negative Affect and Control group with Low Negative Affect).

For valid and invalid trials, we found that only in valid trials the experimental group with high negative affect, compared to the control group with low negative affect, made more errors in trials where the phobic image was presented, ($t(36)=2.296$, $p<0.05$), than in trials where the non non-phobic image was presented ($t(36)=1.056$, $p=0.298$) (see Figure 3.5).

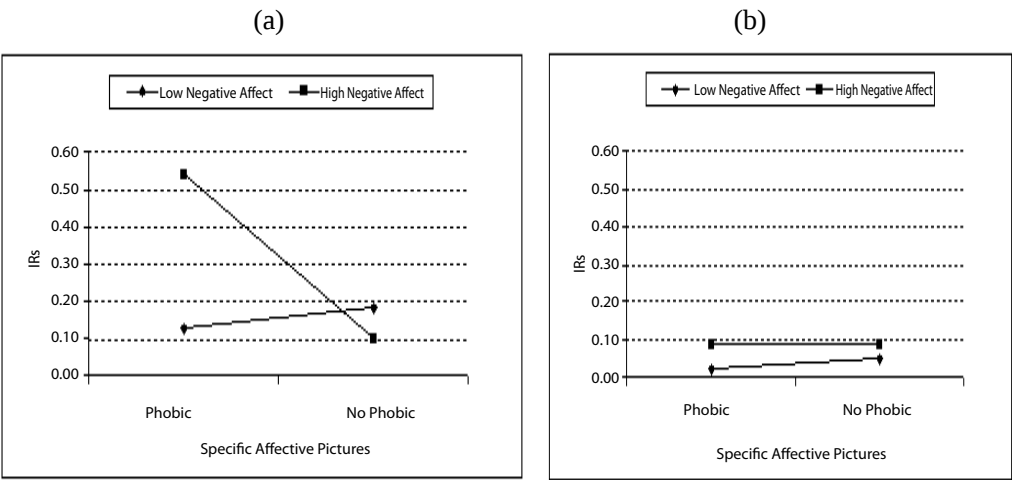


Figure 3.4. Average number of IRs after phobic and non-phobic image presentation for Experimental (a) and Control (b) group regarding Low and High negative affect.

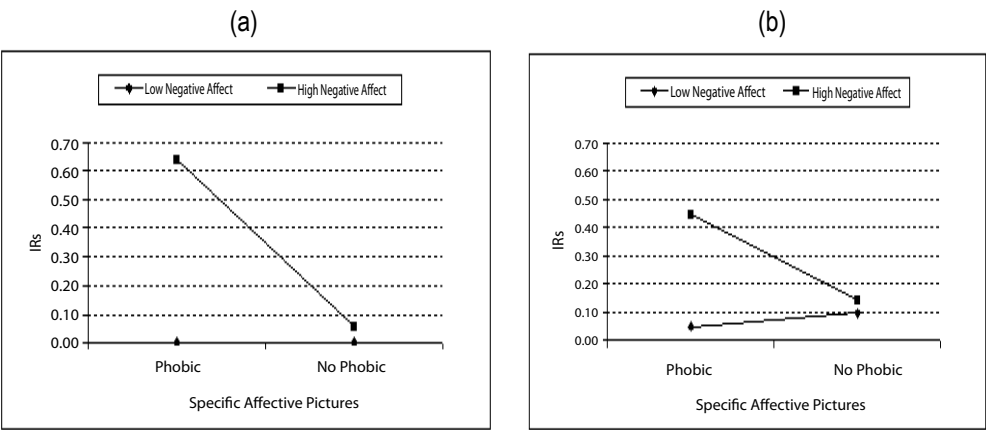


Figure 3.5. Average number of IRs after phobic and non-phobic image presentation for each group in Valid (a) and Invalid (b) trials.

3.3.3. Subjective Measures

This analysis was restricted to the Self-Assessment Manikin of the phobic and non-phobic images in participants from the experimental group with high negative affect and participants from the control group with low negative affect. Participants from the experimental group with high negative affect assessed the phobic images as significantly more unpleasant ($t(36)=8.520$, $p<0.001$), more arousing ($t(36)=6.205$, $p<0.001$), less controllable ($t(36)=8.135$, $p<0.001$), and eliciting higher external attention ($t(36)=4.702$, $p<0.0001$) than control participants with low negative affect. No significant differences were found between both groups in the ratings of the non-phobic images in any of the SAM scales (see Table 3.1).

Table 3.1. Mean (and standard deviation) SAM scores after phobic and non-phobic images presentation for each group

	Valence		Arousal		Dominance		Attention	
	Phobic	Non-Phobic	Phobic	Non-Phobic	Phobic	Non-Phobic	Phobic	Non-Phobic
Experimental Group High Negative Affect	1.88 (1.32)	7.02 (1.30)	8.10 (1.14)	3.53 (1.69)	1.96 (1.29)	5.83 (1.52)	7.66 (1.83)	4.70 (1.64)
Control Group Low Negative Affect	5.06 (0.97)	6.59 (1.37)	5.25 (1.62)	4.12 (1.68)	5.25 (1.20)	5.51 (0.79)	5.44 (1.00)	4.29 (1.30)

4. DISCUSSION

Our findings will be discussed following the same sequence of analyses presented in the previous section and relating those findings to the key theoretical issues raised in the introduction.

As regards the first analysis (sub-analysis 1), our findings have three relevant implications. Firstly, they support the hypothesis that emotional stimuli capture and drive attention producing difficulties in stimulus disengagement. The result is an interference in attentional tasks following perception of highly arousing emotional stimuli, whether positive or negative, in comparison with perception of neutral low arousing ones. In our study, a significant effect was found of the affective arousal of standard pleasant and unpleasant images impairing performance on the attentional task. The viewing of those images produced longer reaction times and a higher number of incorrect responses than neutral images in all participants (Chen et al., 2002; Cisler et al., 2007; Schimmack, 2005).

Secondly, they support the *right hemisphere hypothesis*. All affective stimuli (pleasant, neutral and unpleasant, as well as phobic and non-phobic), presented in the left visual field (right hemisphere), generated more emotional interference than the same stimuli presented in the right visual field (left hemisphere). This effect was independent of stimulus valence and arousal (Borod et al., 2001). It is unclear why neutral images, necessarily with low arousal, also impair performance. It might be argued that all IAPS images, including those assessed as neither very pleasant nor very unpleasant, are nevertheless emotional since they represent natural scenes which, in our study, always contained people.

Thirdly, according to Duckworth et al. (2000) and Ventura et al. (2002), it would be expected shorter reaction times when participants are viewing pleasant images compared to unpleasant ones due to compatibility between the type of movement (approach) and the motivational system activated by the images (appetitive). Our results show delayed reaction times when viewing both unpleasant and pleasant images. The delayed reaction times when viewing unpleasant images can be indeed explained as due to the incompatibility of the requested movement (approach) with the motivational system activated by the image (avoidance). Garcia Pereira et al. (2006) offer an explanation for the lack of faster reaction times when participants view pleasant images (of erotic content): the potentially conflictive reaction (sense of shame) when viewing those images in an experimental context.

As regards the results of the second analysis (sub-analysis 2), our findings also have relevant implications. The higher RTs and IRs shown by all participants in trials where phobic images are presented, compared to non-phobic ones, might be explained as due to an arousal effect. Nevertheless, they can also be explained as due to the valence of the stimuli (their unpleasantness). In this sub-analysis, there were no pleasant images. All images were unpleasant and highly arousing (phobic). However, according to the hypervigilance hypothesis, the higher RTs and greater number of IRs that occur when participants are viewing phobic images, should occur more in invalid trials than in valid ones, exactly the opposite as actually happens (Stormack et al., 1995).

Two complementary alternatives can explain this reversal of the expected attentional effect in valid and invalid trials. On one hand, according to Beck and collaborators (1985), the hypervigilance shown by phobic participants toward their own fear stimuli would make them to get engaged to those stimuli, thus increasing the difficulty to disengage in order to respond quickly to the target presented in the same visual field (valid trials). On the other hand, according to Foa and Kozak (1986), the reaction times and incorrect responses are higher in valid trials because phobic participants would change their attention to the opposite visual field in order to avoid the threatening stimulus. This attentional change would increase the cost of reengaging to stimuli presented in the visual field where the target appears (the same as the threatening stimulus). The *hypervigilance-avoidance hypothesis* (Amir, Foa & Coles, 1998; Mogg, Bradley, Bono & Painter, 1997) can be considered a compromise between these opposite alternatives. This hypothesis proposes that both types of attentional biases (hypervigilance and avoidance) may occur sequentially: hypervigilance in initial stages and avoidance in later ones.

In our study, phobic participants showed delayed RTs in trials where phobic images, compared to non-phobic ones, were presented in short SOA intervals (100 ms). Thus, the phobic participants seemed to be automatically engaged to phobic images presented for short periods, therefore showing difficulty in disengaging from them. This result is consistent with the *hypervigilance-avoidance hypothesis* since this hypothesis assumes that the participant's engagement to phobic stimuli occurs at a pre-attentive or not conscious level (during short presentations) and not at an attentive or conscious one (during long presentations) in which disengagement or avoidance would be more probable (Mogg et al., 2004). The result is also consistent with the notion of *fear preparedness*, i.e., the idea that individuals show unintentional and preferential processing and facilitated attention toward phylogenetically prepared threatening stimuli (Lipp & Derakshan, 2005; Öhman et al., 2001).

As regards the results of our third analysis (sub-analysis 3), they strengthen the findings of our previous analyses highlighting, at the same time, the relevance of individual differences in anxiety and negative affect. Phobic participants with high negative affect showed greater interference in responding to the target after phobic image presentations than phobic participants with low negative affect and than control participants with both high and low negative affect. Furthermore, when the analysis is restricted to the two extreme groups (phobic participants with high negative affect and control participants with low negative affect), significant differences are observed between both groups, concerning reaction times and incorrect responses, in valid trials with short SOA after phobic image presentation. These finding support the idea that emotional modulation of attention is amplified in phobic participants with high negative affect due to the addition of the anxiety levels (phobia) and

the negative affect (mood) that they inform of (Buodo et al., 2006; Cisler et al., 2007; Vassilopoulos, 2005).

Regarding the subjective measures, as expected, phobic participants reported more negative affect and more anxiety, both as a trait (in general) and as a state (after the experimental tasks), than control participants. They also assessed the phobic images as significantly more unpleasant, more arousing, less controllable, and eliciting higher external attention than control participants.

These differences were even higher when only the extreme groups (experimental participants with high negative affect and control participants with low negative affect) were compared. However, in this later comparison, the differences observed concerning the assessment by all participants of non-phobic images (more pleasant, less arousing and more controllable for experimental than control participants) disappeared.

The explanation in terms of 'emotional relief' experienced by phobic participants when processing non-phobic images does not seem tenable when negative affect is also taken into consideration.

In general, our findings are consistent with the *cascade model of defensive reactions* (Bradley & Lang, 2000). Bradley and collaborators (2001) propose that the participants in a laboratory context react to unpleasant images (in this case, phobic ones) in a similar way to an animal *freezing* response: participants are directed toward the stimulation source, processing the context in a detailed manner, recovering important information from memory and implicitly preparing themselves for action.

This freezing-like reaction would explain the slowing down effect and the higher error probability when pressing the key after the unpleasant images in phobic participants (Duckworth et al., 2000; Garcia Pereira et al., 2006; Ventura et al., 2002). The tendency of control participants to show the same effect can be explained by the fact that the phobic images selected by phobic participants (non-phobic for control participants), due to their content (mainly, spiders, snakes, cockroaches, rats, worms, and blood), tended to produce higher arousal and negative valence than the non phobic images also selected by phobic participants (mainly, dogs, deep water, pigeons, and heights).

The *cascade model of defensive reactions* can also explain the simultaneous combination of hypervigilance and avoidance observed in attentional tasks when threatening stimuli are used as signals of the target.

The cascade model assumes a sequence of four defense reactions to the presence of danger or threat as a function of the proximity of the danger (arousal level) and the availability of an escape route: attentive freezing (when the danger is first detected at a safe distance), flight (when the danger is approaching and a escape route is available), fight (when the danger is approaching and no escape route is available), and tonic immobility (when a dominant predator has already made physical contact with the prey). The analogy of this sequence is observed in humans when psychophysiological responses to phobic and defense stimuli are recorded (Vila et al., 2007).

The initial defense response is usually an attentional response (passive defense), accompanied by bradycardia, followed by a motivational response in preparation for flight or fight (active defense), accompanied by tachycardia. The same analogy could be applied for the attentional bias effect. Under this theoretical framework, a passive (hypervigilance) and active (avoidance) defense sequence could explain the attentional bias reported in the literature and found in our study.

The implications of these findings must be tempered by two main limitations of our study: (a) the sub-clinical character of our experimental group, and (b) the differences in arousal and unpleasantness of the phobic and non-phobic images selected by the fearful participants. Thus, future research should take into account the use of highly arousing visual stimuli for both potentially phobic and non-phobic images in the clinical target population. Assuming these limitations, our results also have some clinical contributions concerning the mechanisms by which exposure therapy is effective in the treatment of phobic patients. The pre-attentive approach toward feared stimuli and their subsequent avoidance may be a key factor in the maintenance of the anxiety disorder. Therefore, the exposure to those stimuli using both brief and long presentations might also be a key factor in their reduction.

In summary, this chapter reviews the factors involved in the emotional modulation of attention and presents the results of a study using a modified version of Posner's signal-target attentional paradigm in a group of people with intense specific fears and a control group with no such fears. Signals were affective images (pleasant, neutral, unpleasant, phobic and non-phobic) presented under manipulation of visual field, laterality and SOA.

Results confirm the emotional modulation of attention and suggest that the factors involved are: a) the arousal of the affective stimuli and their visual field presentation (hemispheric dominance) when non-specific affective stimuli are examined, b) the arousal and the negative valence of the affective stimuli when specific phobic stimuli and phobic individuals are examined, c) the pre-attentive hypervigilance and attentive avoidance induced by the phobic stimuli in phobic individuals when signals are presented using a short SOA interval in the same visual field than the target (valid trials), and d) the high negative affect of phobic individuals that potentiates the sequence of defense reactions (hypervigilance and avoidance) to the threatening stimuli.

Present results highlight the relevance of attentional bias in emotional information processing and the role of hypervigilance and avoidance in healthy and sub-clinical population and in people with high and low negative affect.

ACKNOWLEDGMENTS

The present research was supported by grants from the Spanish Ministry of Science and Technology (project PHB2004-0114-PC), the European Union (project SEJ2004-07956/PSI) and the Junta de Andalucía (research group HUM-388).

APPENDIX: THE ITALIAN VERSION OF THE OBQ (OBQ-I46)

This inventory lists different attitudes or beliefs that people sometimes hold. Read each statement carefully and decide how much you agree or disagree with it.

For each of the statements, choose the number matching the answer that best describes how you think. Because people are different, there are no right or wrong answers.

To decide whether a given statement is typical of your way of looking at things, simply keep in mind what you are like most of the time.

Use the following scale:

1	2	3	4	5	6	7
Disagree	Disagree	Agree a	Neither agree	Agree a	Agree	Agree very
very much	moderately	Little	nor disagree	little	moderately	much

In making your ratings, try to avoid using the middle point o the scale (4), but rather indicate whether you usually disagree or agree with the statements about your own beliefs and attitudes.

1. Having control over my thoughts is a sign of good character

1	2	3	4	5	6	7
---	---	---	---	---	---	---

2 If I imagine something bad happening, then I am responsible for making sure it doesn't happen

1	2	3	4	5	6	7
---	---	---	---	---	---	---

3. If I don't control my unwanted thoughts, something bad is bound to happen

1	2	3	4	5	6	7
---	---	---	---	---	---	---

4. When I hear about a tragedy, I can't stop wondering if I am responsible in some way

1	2	3	4	5	6	7
---	---	---	---	---	---	---

5. There is only one right way to do things

1	2	3	4	5	6	7
---	---	---	---	---	---	---

6. I would be a better person if I gained more control over my thoughts

1	2	3	4	5	6	7
---	---	---	---	---	---	---

7. Things should be perfect according to my own standards

1	2	3	4	5	6	7
---	---	---	---	---	---	---

8. The more distressing my thoughts are, the greater the risk that they will come true

1	2	3	4	5	6	7
---	---	---	---	---	---	---

9. I can have no peace of mind as long as I have intrusive thoughts.

1	2	3	4	5	6	7
---	---	---	---	---	---	---

10. I must know what is going on in my mind at all times so I can control my thoughts

1 2 3 4 5 6 7

11. In order to be a worthwhile person, I must be perfect at everything I do

1 2 3 4 5 6 7

12. It is ultimately my responsibility to ensure that everything is in order

1 2 3 4 5 6 7

13. Even if harm is very unlikely, I should try to prevent it at any cost

1 2 3 4 5 6 7

14. For me, having bad urges is as bad as actually carrying them out

1 2 3 4 5 6 7

15. I must think through the consequences of even my smallest actions

1 2 3 4 5 6 7

16. If I can't do something perfectly, I shouldn't do it at all

1 2 3 4 5 6 7

17. I must be ready to regain control of my thinking whenever an intrusive thought or image occurs

1 2 3 4 5 6 7

18. Even minor mistakes mean a job is not complete

1 2 3 4 5 6 7

19. If I have aggressive thoughts or impulses about my loved ones, this means I may secretly want to hurt them

1 2 3 4 5 6 7

20. If I have an intrusive thought while I'm doing something, what I'm doing will be ruined

1 2 3 4 5 6 7

21. In all kinds of daily situations, failing to prevent harm is just as bad as deliberately causing harm

1 2 3 4 5 6 7

22. Avoiding serious problems (e.g., illness or accidents) requires constant effort on my part

1 2 3 4 5 6 7

23. For me, not preventing harm is as bad as causing harm

1 2 3 4 5 6 7

24. I should make sure others are protected from any negative consequences of my decisions or actions

1 2 3 4 5 6 7

25. If I exercise enough will-power, I should be able to gain complete control over my mind

1 2 3 4 5 6 7

26. For me, things are not right if they are not perfect

1 2 3 4 5 6 7

27. Having nasty thoughts means I am a terrible person

1 2 3 4 5 6 7

28. If I do not take extra precautions, I am more likely than others to have or cause a serious disaster

1 2 3 4 5 6 7

29. If I don't do as well as other people, that means I am an inferior person

1 2 3 4 5 6 7

30. In order to feel safe, I have to be as prepared as possible for anything that could go wrong

1 2 3 4 5 6 7

31. To avoid disasters, I need to control all the thoughts or images that pop into my mind

1 2 3 4 5 6 7

32. I should not have bizarre or disgusting thoughts

1 2 3 4 5 6 7

33. Having a blasphemous thought is as sinful as committing a sacrilegious act

1 2 3 4 5 6 7

34. I should be able to rid my mind of unwanted thoughts

1 2 3 4 5 6 7

35. For me, even slight carelessness is inexcusable when it might affect other people

1 2 3 4 5 6 7

36. I must be the best at things that are important to me

1 2 3 4 5 6 7

37. If my actions could have even a small effect on a potential misfortune, I am responsible for the outcome

1 2 3 4 5 6 7

38. Even when I am careful, I often think that bad things will happen

1 2 3 4 5 6 7

39. Having intrusive thoughts means I'm out of control

1 2 3 4 5 6 7

40. Even if harm is very unlikely, I should try to prevent it at any cost

1 2 3 4 5 6 7

41. I must keep working at something until it's done exactly right

1 2 3 4 5 6 7

42. To me, failing to prevent a disaster is as bad as causing it

1 2 3 4 5 6 7

43. If I don't do a job perfectly, people won't respect me

1 2 3 4 5 6 7

44. If I take sufficient care, I can prevent any harmful accident from occurring

1 2 3 4 5 6 7

45. Having a bad thought is morally no different than doing a bad deed

1 2 3 4 5 6 7

46. No matter what I do, it won't be good enough

1 2 3 4 5 6 7

REFERENCES

- Amir, N., Foa, E., & Coles, M. (1998). Automatic activation and strategic avoidance of threat-relevant information in social phobia. *Journal of Abnormal Psychology, 107*, 285-290.
- Amir, N., Elias, J., Klumpp, H., & Preworski, A. (2003). Attentional bias to threat in social phobia: facilitated processing of threat or difficulty disengaging attention from threat?. *Behavior Research and Therapy, 41*, 1325-1335.
- Azevedo, T., Volchan, E., Imbiriba, L., Rodrigues, E., Oliveira, J., Oliveira, L., et al. (2005). A freezing-like posture to pictures of mutilation. *Psychophysiology, 42*, 255-260.
- Beck, A. T., Emery, G., & Greenberg, R. (1985). *Anxiety disorders and phobias: a cognitive perspective*. New York: Basic Books.
- Borod, J., Zgaljardic, D., Tabert, M. & Koff E. (2001). Asymmetries of emotional perception and expression in normal adults. In Gainotti, G. (Ed.), *Handbook of Neuropsychology. Emotional Behavior and its Disorders* .(pp.181-205). Ámsterdam: Elsevier.
- Bradley, M., Codispoti, M., Cuthbert, B., & Lang, P. (2001). Emotion and motivación I: Defensive and appetitive reactions in Picture processing. *Emotion, 1*, 276-298.
- Bradley, M.M., & Lang, P. (1994). Measuring emotion: The Self-Assessment Manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*, 49-59.
- Buodo, G., Sarlo, M., Codispoti, M. & Palomba, D. (2006). Event-related potentials and visual avoidance in blood phobics: is there any attentional bias?. *Depresión and Anxiety, 23*, 304-311.
- Chen, Y., Ehlers, A., Clark, D. & Mansell, W. (2002). Patients with social phobia direct their attention away from faces. *Behaviour Research and Therapy, 40*, 677-687.

- Cisler, J.M., Ries, B.J., & Widner, R. L. (2007). Examining information processing biases in spider phobia using the rapid serial visual presentation paradigm. *Journal of Anxiety Disorders*, 21 (8), 977-990.
- Compton, R. (2000). Ability to disengage attention predicts negative affect. *Cognition and Emotion*, 14 (3), 401- 415.
- Di Nardo, P.A., Brown, T.A., & Barlow, D.H. (1994). *Anxiety Disorders Interview Schedule: Life-time Version (ADIS-IV-L)*. Albany NY: Phobia and Anxiety Disorders Clinic.
- Duckworth, K. L., Bargh, J. A., Garcia, M., & Chaiken, S. (2002). The automatic evaluation of novel stimuli. *Psychological Science*, 13, 513-519.
- Edelstein E. & Guillath O. (2008). Avoiding Interference: Adult Attachment and Emotional Processing Biases. *Personality and social psychology bulletin*, 34 (2), 171-181.
- Foa, E., & Kozak, M.(1986). Emotional processing of fear: Exposure to corrective information. *Psychological Bulletin*, 99, 20-35.
- Fox, E., Russo, R., Bowles, R. & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety?. *Journal of Experimental Psychology. General*, 130 (4), 681-700.
- Garcia Pereira, M., Volchan, E., Guerra, G., Oliveira, L., Ramos R., Machado,W., & Pessoa, L. (2006). Sustained and transient modulation of performance induced by emotional picture viewing. *Emotion*, 6 (4), 622-634.
- Goldberg, E., & Costa, L. (1981). Hemisphere differences in the acquisition and use of descriptive systems. *Brain Lang.* 14 (1),144-73.
- Harman, C., Rothbart, M. & Posner, M. (1997). Distress and attention interactions in early infancy. *Motivation and Emotion*, 21, 27-43.
- Heinrichs, N., & Hofman, S.(2001). Information processing in social Phobia: a critical review. *Clinical Psychology Review*, 21 (5), 751-770.
- Joffily, M., Jandre, F., & Volchan, E. (2006). A mathematical representation of emotional concepts: valence, arousal and attention. University of Río de Janeiro, PhD Thesis.
- Joormann, J. (2004). Attentional bias in dysphoria: The role of inhibitory processes. *Cognition and Emotion*, 18, 125-148.
- Koster, E., Crombez, G., Van Damme, S., Verschuere, B., & De Houwer, J. (2004). Does threat capture and hold attention? *Emotion*, 4, 312-317.
- Koster, E., Crombez, G., Verschuere, B., & De Houwer, J. (2004). Selective attention to threat in the dot probe paradigm: Differentiating vigilance and difficult to disengage. *Behaviour Research and Therapy*, 42, 1183-1192.
- Koster, E., De Raet, R., Goeleven, E., Franck, E., & Crombez, G. (2005). Mood-congruent attentional bias in dysphoria: maintained attention to and impaired disengagement from negative information. *Emotion*, 5 (4), 446-455.
- Lang, P. (1980). Behavioral treatment and bio-behavioral assessment: computer applications. En J.B. Sidowski, J.H. Jonson y T. A. Williams (Eds.). *Technology in mental health care delivery systems* (pp. 119-137). Norwood, NJ: Ablex.
- Lang, P. (1995). The emotion probe: Studies of motivation and attention. *American Psychologist*, 50 371-385.
- Lang, P., Bradley, M., & Cuthbert, B. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F.Simons, & M. T. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 97-135). Mahwah, NJ: Lawrence Erlbaum.

- Lang, P.J., Bradley, M.M. & Cuthbert, B.N. (1999). *International affective picture system (IAPS): Instruction manual and affective ratings* (Tech. Rep. No. A-4). Gainesville, FL: University of Florida, The Center for Research in Psychophysiology.
- Lang, P., Davis, M., & Ohman, A. (2000). Fear and anxiety: Animal models and human cognitive psychophysiology. *Journal of Affective Disorders*, 61, 137–159.
- Lipp, O. & Derakshan, N. (2005). Attentional bias to pictures of fear-relevant animals in a dot probe task. *Emotion*, 5 (3), 365–369.
- MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in the emotional disorders. *Journal of Abnormal Psychology*, 95, 15–20.
- Mathews, A. & Klug, F. (1993). Emotionality and interference with color-naming in anxiety. *Behavior Research Therapy*. 31, 57–62
- Mathews, A. & MacLeod, C. (1994). Cognitive approaches to emotion and emotional disorders. *Annual Review of Psychology*, 45, 25–50.
- Mogg, K. Bradley, B., Bono, J., & Painter, M. (1997). Time course of attentional bias for threat information in non-clinical anxiety. *Behaviour Research and Therapy*, 35, 297–303.
- Mogg, K. & Bradley, B. (2002). Selective orienting of attention to masked threat faces in social anxiety. *Behaviour Research and Therapy*, 40, 1403–1414.
- Mogg, K., Bradley, P., Miles, F., & Dixon, R. (2004). Brief Report: Time course of attentional bias for threat scenes: Testing the vigilance-avoidance hypothesis. *Cognition and Emotion*, 18 (5), 689–700.
- Moltó, J., Montañés, S., Poy, R., Segarra, P., Pastor, M.C., Tormo, M.P., Ramírez, I., Hernández, M.A., Sánchez, M., Fernández, M.C., & Vila, J. (1999). Un nuevo método para el estudio experimental de las emociones: The International Affective Picture System (IAPS). Adaptación española. *Revista de Psicología General y Aplicada*, 52, 55–87.
- Öhman, A., Flykt, A. & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General*, 130 (3), 466–478.
- Posner, M.I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32, 3–25.
- Posner, M. (1986). A framework for relating cognitive to neural systems. In W.C. McCallum, R. Zappolli, & F. Denoth (Eds.). *Cerebral psychophysiology: Studies in event-related potentials* (EEG Suppl. 38, pp. 155–166) Amsterdam: Elsevier.
- Posner, M., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma y D.G. Bouwhuis (Eds.), *Attention and performance: X. Control of language processes* (pp. 531–556). Hove, UK: Lawrence Erlbaum Associates Ltd.
- Posner, M., Cohen, Y., & Rafal, R. (1982). Neural systems control over spatial orienting. *Philosophical Transaction Royal Society of London Series B*, 2908, 187–198.
- Richards, A., French, C., & Dowd, R. (1995) Hemisphere asymmetry and the processing of emotional words in anxiety. *Neuropsychología*, 33, 835–841.
- Robles, R., & Páez, F. (2003). Estudio sobre la traducción al español y propiedades psicométricas de las escalas de afecto positivo y negativo (PANAS). *Salud Mental* 26, 69–75.
- Schimmack, U. (2005). Attentional interference effects of emotional pictures: threat, negativity, or arousal?. *Emotion*, 5 (1), 55–66.

- Spielgerber, C.D., Gorsuch, R.L., & Lushene, R.E. (1970). *Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Stanford University Press.
- Stormark, K.M., Field, N.P., Hugdahl, K., & Horowitz, M. (1997). Selective processing of visual alcohol cues in abstinent alcoholics: an approach-avoidance conflict?. *Addictive Behaviors*, 22 (4), 509-519.
- Stormark, K., Nordby, H. & Hugdahl, K. (1995). Attentional shifts to emotionally charged cues: Behavioral and ERP data. *Cognition and Emotion*, 9, 507-523.
- Van Strien, J., & Heijt, R. (1995). Altered visual field asymmetries for letter naming and letter matching as a result of concurrent presentation of threatening and nonthreatening words. *Brain and Cognition*, 29, 187-203.
- Vassilopoulos, S. (2005). Social Anxiety and the Vigilance-Avoidance Pattern of Attentional Processing. *Behavioural and Cognitive Psychotherapy*, 33, 13-24.
- Viedma-del Jesus, M.I., Martínez, M., Carmelo, M., y Vila, J. (2008). *Library of visual phobic pictures*. Technical report. University of Granada.
- Vila, J., Guerra, P., Muñoz, M.A., Vico, C., Viedma-del Jesús, M.I., Delgado, L.C., Perakakis, P., Mata, J.L. & Rodríguez, S. (2007). Cardiac defense: From attention to action. *International Journal of Psychophysiology*, 66, 169-182.
- Vila, J., Sánchez, M., Ramírez, I., Fernández, M.C., Cobos, P., Rodríguez, S., Muñoz, M.A. Tormo, M.P., Herrero, M., Segarra, P., Pastor, M.C., Montañés, S., Poy, R., & Moltó, J. (2001). El Sistema Internacional de Imágenes Afectivas (IAPS): Adaptación española. Segunda parte. *Revista de Psicología General y Aplicada*, 54 (4), 635-657.
- Watson, D., Clark, L.A., & Tellegen, A. (1988). Development and validation of brief measures of Positive and Negative Affect: The PANAS scales. *Journal of Personality and Social Psychology*, 54, 1063-1070.
- Wentura, D., Rothermund, K., & Bak, P. (2000). Automatic vigilance: The attention-grabbing power of approach- and avoidance-related social information. *Journal of Personality and Social Psychology*, 78, 1024-1037.

Reviewed by Lourdes Anllo-Vento (University of California, San Diego, USA) and Elisabeth Mackay (University of Granada, Spain). It is the author's responsibility to contact the reviewer and take into account any suggestions or comments.

Chapter 15

THE MODERATING EFFECT OF SWITCHING COSTS IN CONSUMERS' RELATIONSHIP DISSOLUTION: A CROSS-CULTURAL ANALYSIS

Carmen Antón Martín^{1*} and Carmen Camarero Izquierdo²⁺

¹Department of Business and Marketing,
University of Valladolid, Spain

²Department of Business and Marketing,
University of Valladolid, Spain

ABSTRACT

The current work analyzes the impact of deficiencies in firms' policies on the customers' intent to break the relationship and the moderating role of switching costs. The work is developed in the context of car insurance services. Concretely, in this context, we differentiate two legal situations that can influence the dissolution process: the countries where consumers comply with the legal obligation to take out car insurance and the countries where consumers feel that the legislation is more permissive and fail to comply with the legal obligation. A comparison of consumers from these two contexts (Spanish and Venezuelan consumers) allows us to derive some conclusions.

Keywords: Relationship dissolution, customer switching behaviour, services marketing

INTRODUCTION

In relationship marketing research, consumer relationship dissolution is a phenomenon that recently has provoked interest in the literature (Hocutt, 1998; Keaveney, 1995; Mittal and Lassar, 1998; and Bansal and Taylor, 1999, 2002). Keaveney (1995) indicates that when

* Tel: +34-983-42-34-13, Fax: +34-983-42-38-99 E-mail: anton@eco.uva.es

+ Tel: +34-983-42-33-32, Fax: +34-983-42-38-99. E-mail: camarero@eco.uva.es

firms lose a customer they are not only losing future earnings and incurring the cost of finding new customers. Customers are becoming increasingly intolerant of inconsistency or mediocrity, and they can choose to dissolve the relationship as soon as any problem arises. They are likely losing a loyal customer, which means giving up high margins. Keaveney and Parthasarathy (2001) likewise warn that consumers' switching behavior in services markets can be particularly serious when the service is delivered continuously, such as in insurance, banking, public services, medical insurance, telecommunications, or generally in services where customers take out a subscription. A premature end to the relationship may mean that customers end up costing the firm more than they bring in.

In this perspective, the objective of the current work is to deepen our understanding of what drives consumers to dissolve a relationship with their service suppliers. Specifically, this current work is based on previous studies assessing determinants of customer intent to switch (Antón et al., 2007, Bansal et al., 2005) and distinguish between two factors impacting relationship ending, factors predisposing towards ending and those precipitating the break, as well as the moderating effect of switching costs. This model of intent to end the relationship is compared for the case of car insurance clients in two differing cultural contexts, Spain and Venezuela. The difference between the two countries revolves around one particular commercial aspect, namely a lax approach to the application of and compliance with the law. Although civil liability insurance for motor vehicles is compulsory in both countries, the impact which current legislation has on consumer purchase behaviour differs. Whereas in Spain consumers are aware of and comply with the legal obligation to take out motor vehicle insurance, law enforcement in Venezuela is less stringent and consumers fail to comply with or are even unaware of the legal obligation to hold such insurance. These situations determine the extent to which consumers are more inclined or more reluctant to end relationship when a supplier fails to live up to expectations. To test empirically the hypotheses proposed we have collected information on car-insurance customers. The work ends with a section presenting our main conclusions and the management implications.

DETERMINANT FACTORS OF RELATIONSHIP DISSOLUTION

Halinen and Tähtinen (2002) theoretically argue for the need to categories the antecedents of dissolution in three levels: predisposing factors, precipitating factors, and attenuating factors of the switching intention. On the theoretical basis of this work, we follow this classification.

Predisposing Factors

The factors that predispose to relationship dissolution are factors that create the conditions in which individuals pay more attention to certain elements that will precipitate dissolution. Duck (1981), in the context of personal relationships, and Halinen and Tähtinen (2002), in the context of business relationships, indicate that predisposing factors already exist when parties enter into a relationship, making it vulnerable to breakdown. These factors could also appear during the relationship; but their effect is not immediate as they need the

accumulation of several incidents to be considered by the consumer. The factors that predispose may be related to the fulfillment of the tasks inherent to the relationship – deficiencies in delivering the service quality required or desired by the consumer – or to the dyadic relationship – decrease in the commitment and interest demonstrated by the firm in the relationship.

In the current proposal, it is considered that the main predisposing factors are deficiencies in the quality of the service (Hess et al., 2003), and the firm's poor efforts to maintain the relationship (Dwyer, Schurr & Oh, 1987).

Poor Service Quality

The quality of the service, from the perspective of Grönroos (1990), is conceptualized from two dimensions: the technical quality (what is delivered to the consumer) and the functional quality (how it is delivered). The most widely-employed measure of this variable is the one proposed by Parasuraman et al. (1988) – the SERVQUAL scale, which consists of five dimensions (tangibles, reliability, responsiveness, assurance and empathy). But this scale has led to some controversy. Brady and Cronin (2001), for example, criticize it and propose an alternative. These authors contend that the perceived service quality is instead made up of three dimensions: the outcome, interaction and physical environment quality. Outcome quality is defined as what the customer obtains when the productive process ends; interaction quality refers to the interaction that takes place while the service is being delivered; and environment quality refers to the conditions of the environment where the service is delivered or the product is sold.

In line with this last definition of quality, Keaveney (1995) suggests that consumers voluntarily exit a relationship because of personal dissatisfaction with the quality of the service received – outcome – or with the service provider – interaction. Many researchers have also suggested that the quality of the customer-organization interaction affects the customer's response to failings in services (Berry, 1995; Kelley & Davis, 1994). The literature on loyalty also indicates that customers value the company's resources and skills very highly – resources and skills that are manifested in the service quality (Mittal & Lassar, 1998). High quality can motivate consumers to strengthen their relationship with their service provider (Hess et al., 2003; Bell et al., 2005), or not (a result obtained by Cronin & Taylor, 1992). What does seem to be clearer is that poor quality or changes in the firm's quality levels provoke a change in consumers' attitudes towards the firm and probably a change in their behavior, as is demonstrated by Bansal et al. (2005), Dabholkar & Walls (1999), Roos (1999) or Zeithaml et al. (1996).

Low Organization Commitment to Customer

In the relationship marketing literature relationship commitment is understood as the desire to develop and maintain long-term exchange relationships, a desire that materializes in the realization of implicit and explicit promises, as well as sacrifices in favor of the economic and social well-being of all the parties having some interest in the relationship (Anderson & Weitz, 1992; Dwyer et al., 1987; Morgan & Hunt, 1994; Walter & Ritter, 2000). The organization's commitment refers to its interest in the consumers and its efforts to maintain their loyalty by adapting to their specific needs, offering frequent communication, special treatment and full information. This attitude from the firm is a result of the assumption that consumers can obtain more value from a relationship of continuing loyalty, and may therefore

forgo the opportunity to choose another supplier to fulfill their needs (Sheth & Parvatiyar, 1995). When consumers perceive added value in the firm's efforts to offer them special treatment to foster their loyalty, they will not switch suppliers. Indeed in some cases the firm's efforts to build customers' loyalty and keep them satisfied excludes any other type of relationship that the consumer might contemplate with any of the firm's competitors (Wathne et al., 2001; Dwyer, Schurr & Oh, 1987), which makes the switching intention even more improbable. In contrast, it can be also maintained that low commitment on the part of the firm reflects its lack of interest in the consumers and will lead to disenchantment, dispelling any intention of loyalty. Breakdown can result from a faulty relational process and consequent dissatisfaction with the relationship itself (Duck, 1991). Not only may expectations about the purpose of the relationship and the quality delivered be disconfirmed, but also expectations about correct or appropriate behaviors. In that line, Rusbult et al. (1983) found a low commitment to be a significant predictor of relationship ending. Also, according to Michalski's (2004) findings in banking services, significant reasons for ending are failures in interactions, not in core services.

Precipitating Factors

The factors that precipitate dissolution are events pushing the consumer to take measures to end the relationship (Duck, 1981; Halinen & Tähtinen, 2002; Halinen, Havila & Salmi, 1999). They may be sudden and dramatic, or form part of a series of events pushing the consumer towards switching suppliers. Like in the previous case, they are failings in the fulfillment of the tasks – sudden price raises – or deficiencies in the interaction in the relationship – sporadic conflicts or episodes that demonstrate the firm's lack of interest in the client – which provoke consumers' anger and lead them to take immediate measures.

In the current proposal, it is considered that the main precipitating factors are the perception of price unfairness (Keaveney, 1995), and the experience of episodes of dissatisfaction or critical incidents (Roos, 1999, 2002).

Unfair Price

There are two tendencies with respect to consumers' perception of the price of the product. The first maintains that consumers regard high prices as a signal of high quality and vice versa (Dodds et al., 1991; Teas & Agarwal, 2000); while the second, in contrast, suggests that low prices can also function as a signal of good value for money (Kirmani & Rao, 2000). In either case, whether a low price is perceived as low quality or a high price is perceived as abusive, when customers are dissatisfied with the value for money or perceive the price to be unfair, their intention will be to switch suppliers (Campbell, 1999; Homburg et al., 2005). Keaveney (1995) suggests that consumers voluntarily switch suppliers because of their personal dissatisfaction with the price paid. This dissatisfaction arises when the consumers perceive the price to be unfair or excessively higher than alternative options. Athanassopoulos (2000) and Bansal et al. (2005) also show that among the reasons consumers switch suppliers, price-related issues are important. Buyers will be conscious of the savings opportunities that other options provide, and the chance to make savings can become a substantial concern (Wathne et al., 2001), as well as the motive for an immediate switch.

Anger Incident

Roos (1999, 2002) analyzes critical incidents as a method for studying consumers' switching decisions. These critical incidents or episodes can affect consumers' behavior, and specifically their intention to dissolve the relationship, either completely or partially. These critical incidents can become anger incidents when the events or episodes have provoked anger and manifest dissatisfaction in the consumer. Bougie, Pieters and Zeelenberg (2003) show that anger is an emotion that, according to emotions theory (Roseman et al., 1994), encloses specific experience content. According to their study, anger also mediates in the relation between consumers' dissatisfaction with the service and their behavioral response – ending the relationship.

Moderating Factors

The factors with a moderating effect are variables that either attenuate or reinforce the effect of the direct determinants. These moderators may be exit barriers associated with the relationship, such as the existence of switching costs, or emotional links created in the relationship, or the lack or unawareness of attractive alternatives. The absence of these barriers, in contrast, could reinforce consumers' switching intention. In the current work we analyse the moderating effect of switching costs.

Switching costs are defined as those costs that consumers associate with the process of switching from one supplier to another (Burnham *et al.*, 2003; Wathne *et al.*, 2001). When consumers manifest that it is not worthwhile switching suppliers, this may be because they are perceiving obstacles to it. These may include searching, transaction and learning costs, discounts for loyalty, habit, emotional costs and cognitive effort, together with the financial, social and psychological risk. Specifically, Burnham *et al.* (2003) describe three types of switching cost: procedural switching costs – these include the economic risk and evaluation costs, and involve expenditure of time and effort; financial switching costs – involve the loss of benefits and financial resources; and relational switching costs – the loss of the personal relationship and the relationship with the brand, which involves psychological and emotional discomfort due to the loss of identity and the breaking of bonds.

Switching costs represent an impediment to exploring new suppliers (Wathne *et al.*, 2001). To the extent that individuals perceive costs or barriers to exit, they will tend to maintain their supplier (Burnham *et al.*, 2003; Lee *et al.*, 2001). If switching costs are low, dissatisfaction with the service quality, price or firm will motivate the intention to switch suppliers. In contrast, if they are high, dissatisfied consumers are likely to manifest a “false loyalty”. Numerous studies have shown that switching costs act as a moderating variable that negatively affects the relation between satisfaction and intention to maintain the relationship (Burnham *et al.*, 2003; Jones *et al.*, 2000; Oliva *et al.*, 1992; Sharma and Patterson, 2000). As the costs rise, the influence of satisfaction on the intention to maintain the relationship declines, and *vice versa*. Then,

- H1. Consumer perception of switching costs restricts the positive impact of factors predisposing towards dissolution (poor quality service and perceived commitment) on consumer intent to dissolve the relationship with the provider.

- H2. Consumer perception of switching costs restricts the positive impact of factors precipitating dissolution (unfair price or anger incident) on consumer intent to dissolve the relationship with the provider.

THE CASE OF CAR INSURANCE: THE MODERATING EFFECT OF SWITCHING COSTS IN DIFFERENT CULTURAL CONTEXTS

In this work we explore relationship dissolution by consumers from a cross-cultural perspective for the case of automobile insurance. Car insurance is a service in which dissolution of a relationship is a problem from the standpoint of the firm and a meditated decision from the consumer viewpoint. This is a service, as Keaveney and Parthasarathy (2001) point out, in which customers' behaviour in switching suppliers may be particularly worrying for the firm, since it does not normally recover costs until customers have spent several years with it. If customers cancel their insurance, the firm can lose a considerable amount of money.

Car insurance services are conditioned by the law. The legal requirements involved in insurance differ depending on the country in which it is taken out. On the one hand there are countries where stringent legislation exists controlling the obligation to have car insurance. Insurance is compulsory by law for all car owners, the penalties for driving without are stiff and the number who fail to comply with the law is low. This is the case for the majority of American states and in European countries. By contrast, in other countries car insurance is governed by laws which are not applied stringently and the number of uninsured drivers is quite high. Such is the case in the majority of Latin-American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Panama, Peru, the Dominican Republic and Venezuela). Uruguay has no compulsory insurance and we failed to find any laws in this respect for Cuba, Haiti, Honduras and Paraguay (Castelo, 2006). Despite what the law lays down for all these countries, the insurance system does not work well and does not cover all risks. The main problem is the low number of cars insured and the number being driven whose policies have expired (Castiglione, 2004). These differences in the law lead to two highly differing purchase contexts and different switching costs which might impact consumers' breaking the relationship. The goal of our work is to assess sensitivity of the dissolution process to membership of either of these cultural and switching costs contexts.

The extent to which switching costs moderate the impact of predisposing and precipitating factors on the intent to break the relationship is conditioned by the consumer attitudes towards the law. Consumers who have a positive attitude towards compliance with the law and are therefore aware of the obligation to take out insurance (either with the current provider or with a new one) will feel bound to take out insurance when breaking the relationship, therefore, they will be reluctant to initiate a switching process. In this case, the moderating effect of switching costs will be higher. On the other hand, consumers who are less aware of the obligation consider dissolution a viable option and feel free to decide whether to acquire insurance will react more intensely and immediately to failings on the part of the firm, therefore, the moderating effect of switching costs will be reduced. If an individual feels free to break with the insurance company without the need to then become

immediately involved in seeking another (since they perceive that being without any insurance is a viable option), the threshold tolerance towards poor company service and failures is likely to be lower. Despite the switching costs, the individuals feel themselves free to take them on or not once the relationships is dissolved, then, the moderating effect of switching costs will be lower.

H3. When consumers feel that the law is permissive (Venezuela), switching costs will have less moderating effect on predisposing (H3a) and precipitating factors (H3b) than when consumers feel that the law is compulsory and strict.

Empirical Study

In order to verify the hypotheses posited, we conducted an empirical study, the results of which we present in this section. We firstly detail the scope of the study and identify the sample chosen for the analysis. We then present the measurement scales for each variable together with their validation and finally comment the outcomes to emerge from the proposed models.

Scope of the Study

As mentioned, the empirical study was performed comparing two countries which clearly differ in their enforcement of the law regarding automobile insurance and which evidence differing consumer behaviour: Spain and Venezuela.

Legislation governing civil liability and motor vehicle insurance has been in force in Spain since 1968, and has undergone various changes which have led to the current text, dating from 2004 and which has been adapted to meet EU requirements. Compulsory civil liability insurance covers personal injury and damage to other vehicles. There is also an EU body in all member states (Insurance Compensation Consortium) which acts as a direct insurer when no private insurance is held, and a Guarantee Fund, in certain cases of lack of insurance or insurer insolvency, etc. Current legislation also aims to speed up the procedure to penalise cases of non-compliance with the obligation to hold insurance. Disobedience of the law in this respect is sanctioned with disqualification from driving in the country, the vehicle being impounded and a heavy fine being imposed. According to data issued by the Spanish Insurance Compensation Body and the Spanish Traffic Authorities (DGT), 6.9% of vehicles on the road in Spain are currently uninsured.

Civil liability insurance has only been mandatory in Venezuela since 2001, although the law has limited effectiveness. Automobile insurance aims not so much to safeguard possible victims of traffic accidents but rather the vehicle insured. Bearing in mind that injured persons do not normally receive compensation and that in general the courts are not ready to deal with such claims, recourse to the law tends to result in only insignificant amounts being awarded (Castelo, 2006). Moreover, drivers are not aware of the obligation to be insured, due to the fact that the law is hardly enforced through a policy of sanctions preventing offences. Many people are not even aware of the existence of this recently introduced law. The high cost of insurance policies on the one hand and unemployment rates on the other means that

over half of all private vehicles owned by Venezuelans are uninsured. Even amongst those who belong to the more favoured socioeconomic spheres, 25% of all vehicles remain uninsured (Study of the Penetration into the Market of Insurance in Venezuela, concluded in September 2003, Datanalisis). The contrast in the degree to which the law regarding car insurance is observed in Spain and Venezuela, as well as people's attitudes towards such legislation may also be linked to the cultural differences prevailing in the two countries. On the basis of Hofstede's framework (1984), Spanish culture demonstrates a greater level of uncertainty avoidance (10-15) than Venezuela (21-22). Uncertainty avoidance indicates to what extent people feel threatened by uncertainty and ambiguity and try to avoid these situations (Hofstede, 2001). Uncertainty-avoiding cultures try to minimize the possibility of such situations and adhering to strict laws and rules, safety and security measures. Clearly, this cultural difference could explain the different behaviours towards automobile insurance regulation: a tendency to violate the law and a laxity in the legislation and a certain tolerance towards the non-fulfilment of the law in Venezuela and law enforcement with economic sanctions in order to reduce the overall level of uninsured drivers in Spain.

Sample and Measurement of Variables

To gather the information, surveys were conducted amongst people who held automobile insurance in Spain and Venezuela. Surveys yielded a sample of 247 individuals in Spain (data gathered during March and April 2005) and 142 in Venezuela (data gathered in July and August 2005). In order to determine the kind of relationship which exists with the insurance firm, respondents were asked how they contacted the firm. In Venezuela a total of 32.9% of the sample habitually contact with their insurance firm through its offices, 14.5% do so by telephone, and the rest through an insurance broker. In the Spanish case, 45.9% of the sample contact with their insurance firm through its offices, 37% do so by telephone, 16.3% through an insurance broker, and 0.7% of them use the internet. Although as pointed out previously drivers have been obliged to take out civil liability insurance in Venezuela since 2001, when respondents were asked whether they were aware of the existence of the law, a large majority, despite holding such insurance, not only stated that they were not aware but that insurance was not compulsory. This supported our argument regarding the lack of law enforcement.

We describe below how we constructed and validated each of the variables. All items were assessed on a five point Likert scale.

Intent to Exit (Dissolution)

Relationship dissolution was measured in the decision-making stage, when consumers consider switching suppliers, the phase that Duck (1982) calls "intra-psyhic". The stage involves intentions, so we cannot be sure that the consumer will actually dissolve the relationship in the near future. But this approach does allow us to undertake a cross-sectional analysis, and it is in line with previous research (Hellier et al., 2003; Hocutt, 1998; Jones et al., 2000; Mittal and Lassar, 1998; Ping, 1994, 1995). The measurement scale used was based on the scale proposed by Ping (1995).

Table 1. Descriptive statistics, reliability and convergent validity(*)

DESCRIPTION	Mean (SD)		Loadings (t-statistic)	
	Spain	Venezuela	Spain	Venezuela
<i>Intent to exit</i> ($\alpha_{SPA}=0.74$ $\rho_{SPA}=0.84$ $AVE_{SPA}=0.66$) ($\alpha_{VEN}=0.92$ $\rho_{VEN}=0.95$ $AVE_{VEN}=0.86$)				
I have considered changing companies	2,05 (1,33)	2,50 (1,42)	0.90 (66.35)	0.92 (54.23)
I have no intention to renew with this company	2,34 (1,56)	2,42 (1,42)	0.60 (9.09)	0.92 (59.00)
I intend to insure my automobile with another company in the future	2,03 (1,33)	2,48 (1,46)	0.90 (56.26)	0.94 (56.85)
<i>Outcomes quality</i> ($\alpha_{SPA}=0.85$ $\rho_{SPA}=0.92$ $AVE_{SPA}=0.87$) ($\alpha_{VEN}=0.92$ $\rho_{VEN}=0.95$ $AVE_{VEN}=0.92$)				
My company responds quickly to my needs	3,63 (1,07)	2,30 (1,38)	0.94 (144.61)	0.96 (86.30)
When I have had a problem my company has responded efficiently	3.73 (1,16)	2.21 (1,32)	0.92 (87.80)	0.96 (90.71)
<i>Interaction quality</i> ($\alpha_{SPA}=0.90$ $\rho_{SPA}=0.92$ $AVE_{SPA}=0.77$) ($\alpha_{VEN}=0.92$ $\rho_{VEN}=0.94$ $AVE_{VEN}=0.82$)				
The attitude of this company's employees demonstrates their willingness to help me	3.35 (1,05)	2.33 (1,21)	0.92 (98.33)	0.92 (65.74)
The attitude of this company's employees demonstrates that they understand my needs	3.39 (0,98)	2.51 (1,21)	0.92 (91.27)	0.87 (26.57)
This company's workers are very competent	2.61 (1,21)	2.19 (1,21)	0.78 (19.21)	0.88 (41.04)
<i>Physical environment quality</i> ($\alpha_{SPA}=0.80$ $\rho_{SPA}=0.90$ $AVE_{SPA}=0.83$) ($\alpha_{VEN}=0.77$ $\rho_{VEN}=0.89$ $AVE_{VEN}=0.81$)				
The offices and branches of my company are modern and well-equipped	3.54 (1,07)	2.30 (1,22)	0.89 (42.00)	0.87 (25.27)
The offices of my company give an image of professionalism	3.42 (1,06)	2.36 (1,18)	0.93 (79.36)	0.92 (89.20)
<i>Price unfairness</i> ($\alpha_{SPA}=0.90$ $\rho_{SPA}=0.95$ $AVE_{SPA}=0.91$) ($\alpha_{VEN}=0.91$ $\rho_{VEN}=0.95$ $AVE_{VEN}=0.91$)				
The price I pay for the service I receive from the insurance company is fair	2.91 (1,22)	2.65 (1,33)	0.95 (123.58)	0.95 (102.0)
The service I receive is good value for money	3.10 (1,17)	2.43 (1,30)	0.95 (135.90)	0.96 (128.1)
<i>Perceived commitment</i> ($\alpha_{SPA}=0.82$ $\rho_{SPA}=0.87$ $AVE_{SPA}=0.65$) ($\alpha_{VEN}=0.83$ $\rho_{VEN}=0.88$ $AVE_{VEN}=0.66$)				
The company maintains a frequent and constant relationship with me	2.37 (1,16)	3.06 (1,42)	0.83 (39.45)	0.81 (21.56)
The company gives me full and useful information about its products	2.83 (1,24)	2.82 (1,33)	0.80 (31.49)	0.81 (25.97)
I feel I get special benefits for being a good customer	2.62 (1,24)	3.13 (1,40)	0.83 (41.81)	0.83 (34.20)
The company is flexible in adapting its offer to my specific needs	2.68 (1,07)	3.04 (1,31)	0.75 (20.89)	0.79 (18.15)
<i>Anger incident</i>				
I have recently had an experience with this company that angered me	2,15 (1,30)	2,35 (1,39)	1.00 (-)	1.00 (-)
<i>Switching costs</i> ($\alpha_{SPA}=0.67$ $\rho_{SPA}=0.85$ $AVE_{SPA}=0.75$) ($\alpha_{VEN}=0.64$ $\rho_{VEN}=0.84$ $AVE_{VEN}=0.74$)				
If I switched my insurance company, I would have to pay high costs	3,26 (1,24)	3,53 (1,39)	0.86 (11.06)	0.84 (7.31)
If I switched my insurance company, I would lose some advantages I have acquired	3,10 (1,37)	3,41 (1,40)	0.87 (12.12)	0.88 (11.53)

Deficient Service Quality

Measuring service quality still seems to be a controversial topic, as we have mentioned. In our case we opted to follow Brady and Cronin's (2001) proposal, which combines those of Grönroos (1990) and Parasuman et al. (1988), and implies that the perception of service quality is founded on three dimensions: the outcome, interaction and physical environment quality. These three dimensions define the base of the perceived service quality, and other second-order dimensions may underlie them. Taking this approach, we measured these three aspects of quality adapting the scale used by these authors.

Low Perceived Commitment

The scale for the firm's commitment as perceived by the consumer was built especially for this current work. We tried to include different aspects that the relationship marketing literature attributes to a service provider's relational orientation policy, on the basis of items proposed by Anderson and Weitz (1992), Gundlach and Cadotte (1995), Kumar et al. (1995a and 1995b), and Mohr and Spekman (1994): willingness to invest; shared information; loyalty and commitment to the customer; or perceived desire to continue.

Price Unfairness

The consumer's perception of an unfair price and poor value for money were each measured by a separate item. These items were built for this current study starting from the results obtained by Keaveney (1995) in her descriptive study of consumers' motives for terminating relationships.

Anger Incident

This variable was measured using a single indicator, where respondents were asked to state if they had had any recent experience with their supplier that had upset them and caused them to lose confidence in the firm.

Switching Costs

To measure switching costs we made use of the proposal by Burnham et al. (2003) – cost in time and effort, financial costs and psychological costs – and the scale used by Sharma and Patterson (2000), to propose a simpler scale of two single indicators measuring these aspects.

Since the measures have been taken from different studies and have been developed in various contexts, it was deemed appropriate to undertake a series of analyses enabling us to determine their psychometric properties and to assess reliability and validity.

Measurement Invariance Test

Our study was carried out in different countries (two contrasting cultures) and therefore testing the invariance of the latent measurements is advisable so as to safeguard a comparison of the measurements between samples or groups. The aim is to test the generalisation or universality of the measurement scales (measurement equivalence) applied to two cultural groups or contexts. Universality of measurements is important to ensure contrasting outcomes are due to real differences and not variations in the way the scale is used or interpreted. In

order to conduct a comparison amongst different groups or cultures the same psychological metric must be used (Maurer et al., 1998). Following the proposal of Steenkamp and Baumgartner (1998), we first assess configural invariance and then metric invariance. For this we used confirmatory factorial analysis (Lisrel 8). Items proposed to measure service quality, perceived price and perceived commitment were previously recoded such that higher values in the items indicated poorer quality, perceived price and commitment.

This reclassification allows us to value the hypotheses along the lines proposed. Given the chi-squared statistic dependence on the size of the sample, the main indicators used to evaluate the model fit are CFI, RMSEA and the χ^2/gl ratio. The value of these indicators meet the established criteria of a CFI above 0.9, RMSEA below 0.07 (Bollen, 1989) and a χ^2/gl ratio between 1 and 5 (Wheaton et al., 1977; Carmines and Mc Iver, 1981).

In order to demonstrate the existence of configural invariance the hypothetical structure must satisfactorily fit both the Spanish and Venezuelan group (Durvasula et al., 2001). In other words, we may state that configural invariance has been verified if non-restricted multi-group CFA shows a good fit. In this case, the measurement model estimations proposed with the multi-group analysis evidence a satisfactory fit (CFI=.97, RMSEA = 0.068 and χ^2/gl = 694.273/334 = 2.07). In the two samples all the lambda values are significant in their respective dimension and are above 0.6. Results indicate a similar factorial structure for the latent measurements in the two groups. Once configural variance has been verified, metric invariance can be tested. The metric invariance test involves evaluating the equality of the factor loadings (lambda values) in the various groups. This equality is required to compare the values of the causal relationships between the groups (beta values). The test is performed with confirmatory factorial analysis on the measurement model, using multisample estimation and the covariance matrix as input data. Two models are compared, the restricted model that forces equality of the lambda value estimators in all the groups and the free model that estimates the unrestricted lambda values. In our case, the difference in the chi-squared (diff χ^2 (19) = 18.21) between the restricted and the free model is not significant and since the restricted measurement model yields an acceptable fit (CFI = 0.97, RMSA = 0.066 χ^2/gl = 712.491/353 = 2.02) we take the metric invariance between the samples analysed as being proved. As analyses have evidenced configural invariance and metric invariance for the Venezuela and Spain samples, then we can test H3. Table 1 shows the set of proposed indicators, descriptive statistics and the estimation of the measurement models. Tables 2, 3 and 4 show the correlation matrices.

Estimation of the Structural Model

Figure 1 shows a graphic representation of the structural model we aim to analyse.

Although the measurement scales of the variables are reflective in nature, as has been evidenced in the previous procedures used to validate the corresponding scales, the explanatory variables we propose in our hypotheses (predisposing factors and precipitating factors) are second order formative constructs as shown in the figure. The formative nature of these variables leads us to opt for the Partial Least Squares (PLS) approach as the estimation model.

Table 2. Correlation matrix (Total)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Poor outcomes quality	1.000									
(2) Poor interaction quality	0.698	1.000								
(3) Poor physical quality	0.518	0.586	1.000							
(4) Low perceived commitment	0.544	0.620	0.445	1.000						
(5) Price unfairness	0.610	0.466	0.350	0.599	1.000					
(6) Anger incident	0.289	0.284	0.126	0.284	0.232	1.000				
(7) Switching costs	-0.247	-0.346	-0.248	-0.279	-0.289	-0.098	1.000			
(8) Predisposing factors	0.818	0.921	0.707	0.816	0.612	0.312	-0.349	1.000		
(9) Precipitating factors	0.618	0.493	0.342	0.607	0.949	0.565	-0.280	0.627	1.000	
(10) Intention to exit	0.453	0.456	0.250	0.448	0.426	0.425	-0.203	0.504	0.505	1.000
Variance extracted	0.896	0.792	0.819	0.653	0.910	-	0.744	0.542	0.663	0.760

Table 3. Correlation matrix (Spain)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Poor outcomes quality	1.000									
(2) Poor interaction quality	0.604	1.000								
(3) Poor physical quality	0.326	0.427	1.000							
(4) Low perceived commitment	0.532	0.539	0.382	1.000						
(5) Price unfairness	0.515	0.310	0.180	0.561	1.000					
(6) Anger incident	0.298	0.282	0.060	0.232	0.232	1.000				
(7) Switching costs	-0.101	-0.229	-0.223	-0.141	-0.167	-0.096	1.000			
(8) Predisposing factors	0.777	0.888	0.584	0.810	0.510	0.302	-0.223	1.000		
(9) Precipitating factors	0.547	0.360	0.180	0.567	0.956	0.507	-0.177	0.534	1.000	
(10) Intention to exit	0.395	0.371	0.146	0.401	0.437	0.361	-0.172	0.443	0.496	1.000
Variance extracted	0.867	0.768	0.829	0.648	0.907	-	0.751	0.476	0.644	0.661

Table 4. Correlation matrix (Venezuela)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Poor outcomes quality	1.000									
(2) Poor interaction quality	0.796	1.000								
(3) Poor physical quality	0.734	0.764	1.000							
(4) Low perceived commitment	0.576	0.720	0.523	1.000						
(5) Price unfairness	0.734	0.642	0.558	0.611	1.000					
(6) Anger incident	0.281	0.293	0.221	0.383	0.367	1.000				
(7) Switching costs	-0.408	-0.473	-0.267	-0.418	-0.414	-0.110	1.000			
(8) Predisposing factors	0.865	0.957	0.824	0.834	0.721	0.344	-0.466	1.000		
(9) Precipitating factors	0.697	0.627	0.533	0.634	0.945	0.651	-0.377	0.709	1.000	
(10) Intention to exit	0.535	0.579	0.402	0.599	0.514	0.517	-0.287	0.620	0.601	1.000
Variance extracted	0.922	0.816	0.809	0.658	0.914	-	0.737	0.609	0.683	0.859

Table 5. Multicollinearity diagnosis

	Total			Spain			Venezuela		
	Tolerance	VIF	CI	Tolerance	VIF	CI	Tolerance	VIF	CI
<i>Predisposing Factors</i>									
<i>Poor outcomes quality</i>	0.475	2.104	3.125	0.575	1.740	2.520	0.326	3.071	4.380
<i>Poor interaction quality</i>	0.386	2.592		0.534	1.873		0.221	4.529	
<i>Poor physical quality</i>	0.630	1.587		0.782	1.278		0.369	2.709	
<i>Low perceived commitment</i>	0.581	1.720		0.622	1.609		0.479	2.087	
<i>Precipitating Factors</i>									
<i>Price unfairness</i>	0.921	1.086	1.335	0.946	1.057	1.267	0.866	1.155	1.469
<i>Anger incident</i>	0.921	1.086		0.946	1.057		0.866	1.155	

Table 6. Path coefficients

	Total		Spain		Venezuela		Test of means
MODEL I	<i>Coefficient</i>	<i>t-statistic</i>	<i>Coefficient</i>	<i>t-statistic</i>	<i>Coefficient</i>	<i>t-statistic</i>	<i>t-statistic</i>
<i>Poor outcome quality → Predisposing factors</i>	0.23	37.27	0.24	25.68	0.22	27.32	2,233
<i>Poor interaction quality → Predisposing factors</i>	0.45	50.78	0.48	34.68	0.43	51.39	2,957
<i>Poor physical e. quality → Predisposing factors</i>	0.17	33.16	0.16	20.31	0.17	25.68	-0,991
<i>Low commitment → Predisposing factors</i>	0.33	37.97	0.37	29.12	0.31	25.82	2,989
<i>Price unfairness → Precipitating factors</i>	0.86	64.77	0.86	56.22	0.81	39.08	2,824
<i>Anger incident → Precipitating factors</i>	0.33	32.26	0.30	27.78	0.35	22.71	-2,698
<i>Predisposing factors → Intent to exit</i>	0.30	5.26	0.24	3.04	0.39	3.58	-1,166
<i>Precipitating factors → Intent to exit</i>	0.32	5.47	0.37	5.42	0.32	3.03	0,380
R^2	0.31		0.291		0.438		
MODEL II			<i>Coefficient</i>	<i>t-statistic</i>	<i>Coefficient</i>	<i>t-statistic</i>	<i>t-statistic</i>
<i>Poor outcome quality → Predisposing factors</i>	0.23	37.04	0.24	26.15	0.22	27.21	2,252
<i>Poor interaction quality → Predisposing factors</i>	0.45	51.70	0.48	34.45	0.43	51.38	2,942

	Total		Spain		Venezuela		Test of means
MODEL II			<i>Coefficient</i>	<i>t-statistic</i>	<i>Coefficient</i>	<i>t-statistic</i>	<i>t-statistic</i>
<i>Poor physical e. quality → Predisposing factors</i>	0.17	31.40	0.16	22.23	0.17	27.26	-1,071
<i>Low commitment → Predisposing factors</i>	0.33	36.52	0.36	30.44	0.31	25.15	3,016
<i>Price unfairness → Precipitating factors</i>	0.86	64.88	0.88	53.35	0.81	36.39	2,647
<i>Anger incident → Precipitating factors</i>	0.33	34.09	0.30	27.73	0.35	22.06	-2,644
<i>Predisposing factors → Intent to exit</i>	0.29	4.59	0.22	3.09	0.41	3.83	-1,513
<i>Precipitating factors → Intent to exit</i>	0.32	5.70	0.37	5.82	0.32	2.90	0,436
<i>Switching costs → Intent to exit</i>	-0.01	0.26	-0.06	1.23	0.01	0.20	-0,952
<i>Predisposing factors × Switching costs → Intent to exit</i>	-0.06	1.50	-0.08	1.68	0.04	0.64	-1,716
R^2	0.318		0.31		0.439		
MODEL III			<i>Coefficient</i>	<i>t-statistic</i>	<i>Coefficient</i>	<i>t-statistic</i>	<i>t-statistic</i>
<i>Poor outcome quality → Predisposing factors</i>	0.23	36.71	0.24	27.28	0.22	26.38	2,275
<i>Poor interaction quality → Predisposing factors</i>	0.45	50.18	0.48	37.27	0.43	49.51	3,078

Table 6. (Continued)

	Total		Spain		Venezuela		Test of means
MODEL III			<i>Coefficient</i>	<i>t-statistic</i>	<i>Coefficient</i>	<i>t-statistic</i>	<i>t-statistic</i>
<i>Poor physical e. quality → Predisposing factors</i>	0.17	31.16	0.16	21.00	0.17	27.16	-1,034
<i>Low commitment → Predisposing factors</i>	0.33	36.58	0.36	29.86	0.31	25.62	3,016
<i>Price unfairness → Precipitating factors</i>	0.86	64.97	0.88	53.05	0.81	36.45	2,645
<i>Anger incident → Precipitating factors</i>	0.33	32.76	0.30	27.04	0.35	23.21	-2,712
<i>Predisposing factors → Intent to exit</i>	0.30	5.06	0.23	2.38	0.39	3.61	-1,262
<i>Precipitating factors → Intent to exit</i>	0.32	5.47	0.37	5.91	0.33	3.14	0,348
<i>Switching costs → Intent to exit</i>	-0.01	0.23	0.06	3.46	0.02	0.27	-0,994
<i>Precipitating factors × Switching costs → Intent to exit</i>	-0.09	2.24	-0.02	0.32	-0.10	1.79	1,022
R^2	0.322		0.294		0.450		

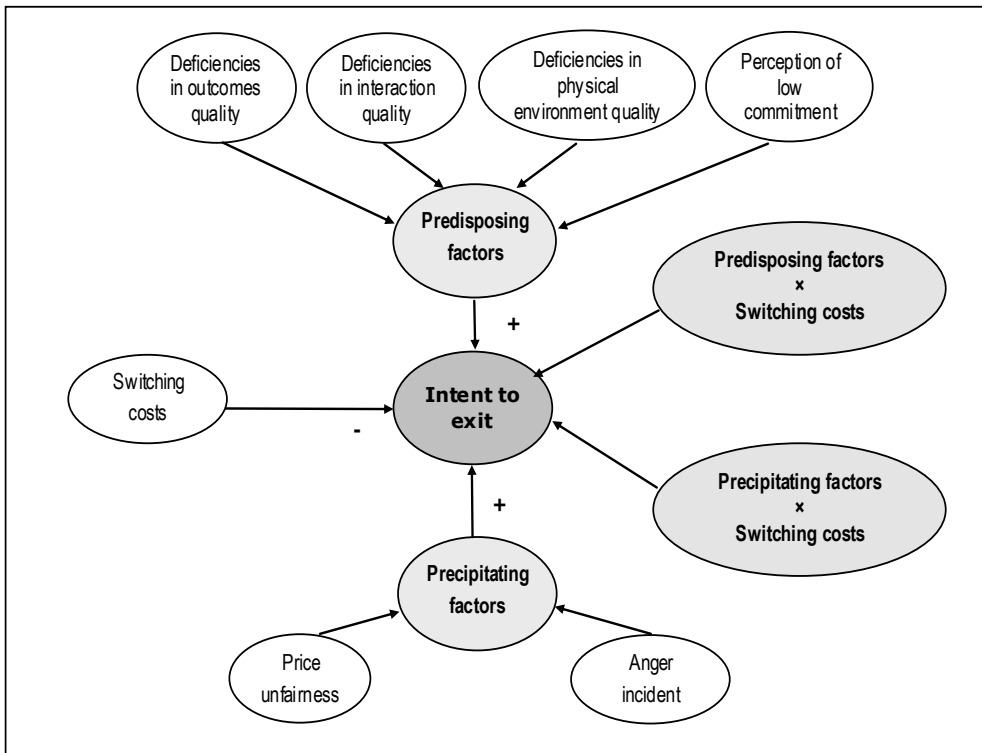


Figure 1. Structural model.

PLS (Chin, 1998; Chin and Newsted, 1999) allows us to estimate second order measurement models comprising a reflective measurement level with a formative measurement level, as is our case.

This approach also allows us to work with variables not normally distributed and is robust for small-to-moderate sample sizes. The model was estimated using Smart PLS for both samples (Spain and Venezuela). The level of statistical significance of the coefficients of both the measurement and the structural models was determined through a bootstrap re-sampling procedure (500 sub-samples were randomly generated). Structural models evaluation is conducted by examining the size and significance of the path coefficients and the R^2 value of the dependent variable.

As pointed out by Diamantopoulos and Winklhofer (2001), a formative measure is essentially a multiple regression with the construct representing the dependent variable and the indicators as the predictors. Therefore correlation among the indicators results in multicollinearity which can lead to instability in coefficients. High collinearity is an undesirable property in formative models as it causes estimation difficulties (Albers and Hildebrandt, 2006). As a result, Diamantopoulos and Winklhofer (2001) suggest using normal regression diagnostics in order to assess formative index validity.

In the Table 5 it appears the tolerance values, the variance inflation factor (VIF) and the condition index (CI). These values, as well as correlation between indicators, demonstrate that multicollinearity is not a problem to the construction of the second-order formative indexes.

In order to form the interactions between the variables, it is not possible to follow the process used for reflective indicators, that is, the multiplication of the constructs' indicators. One approach for formative indicators would be to follow a two step construct score procedure. The first step would entail using the formative indicators in conjunction with PLS to create underlying construct scores for the predictor and moderator variables. Step two would then consist of taking those single composite scores to create a single interaction term (Chin et al, 1996). Following this procedure, we have estimated three models: Model I, Model II and Model III. Model I only considers the effect of predisposing and precipitating factor son dissolution; this model will be the base for comparison. Next, we have introduced the direct effect of switching costs and the interaction of switching costs with the predisposing (Model II) and the precipitating factors (Model III). Each model has been estimated for the total sample, for the Spanish sample, and for the Venezuelan sample. The results of estimations appear on Table 6 (standardized path coefficients and t-statistics).

Having estimated the model for each sample, and since current PLS software does not yet permit multisample analysis, we compared the models by means of measurement contrast for each coefficient (Chin, 2005). Table 6 shows the results of the measurement tests. The test is conducted using a unilateral contrast, since the hypotheses have been formulated in a single direction.

As can be seen from the results in Table 6, for the total simple, the switching costs have not a significant effect in the dissolution and only moderate the effect of precipitating factors on the intent to break. Therefore, we confirm the hypothesis H2, but we have to reject H1.

When we estimate the three models individually for the Spanish and the Venezuelan samples, we observe both, that the process of dissolution is better explained in the case of Venezuela (higher R^2 value) and that switching costs have not a significant direct effect in any country. Further, the results indicate that the index of the predisposing and the precipitating variables is not formed the same way in Spain as it is in Venezuela. For Venezuelan consumers, failures in the quality of results and the quality of interaction and the lack of commitment by the firm are far less important in the overall predisposing factors than for Spanish consumers. In the case of precipitating factors, we observe that an unfair price has less effect in Venezuela than in Spain, whereas it just occurs the contrary for the anger incident. Then, an anger incident is more relevant for the Venezuelan consumers, while an unfair price has a higher loading on precipitating factors for Spanish consumers.

As regards the interaction between the switching costs and the predisposing factors, its impact seems to be significant in the case of Spain, whereas for Venezuela its impact on the intention to dissolve is not significant. Since the differences between the two countries are significant, the hypothesis H3a is confirmed, positing a minor moderating effect of switching costs in predisposing factors when the legislation is more stringent.

Finally, as it refers to the moderating effect of switching costs in precipitating factors, there are not significant differences between Spain and Venezuela. Then, we reject the hypothesis H3b. Nevertheless, the results indicate that the switching costs soften significantly the impact of precipitating factors on the intent to break in Venezuela, but not in Spain. In this case, and contrary to our expectations, the switching costs reduce the effect of precipitating factors (unfair price and anger incident) in Venezuela, where the law is more permissive, but not in Spain, where the consumers feel the legal obligation.

Discussion

By adopting a cross-cultural approach, the current study aims to explore the process by which a consumer dissolves a relationship with a service provider. Focusing on the area of car insurance as a service, the existence of contrasting legislation, which may be more or less lenient and applied with a differing degree of severity, leads individuals to adopt contrasting attitudes or perceptions regarding the obligation to take out this kind of insurance. The fact that in certain countries individuals are fully aware of the obligation to acquire car insurance, whereas in others they feel free or more inclined to break the law, becomes one aspect of a country's commercial culture which may determine the degree to which consumers are sensitive towards certain variables impacting the intention to dissolve the relation.

We have differentiated two determinant factors of consumer switching intention: factors predisposing towards dissolution (deficiencies in service quality and company commitment towards the consumer) and factors precipitating dissolution (unfair pricing and anger incidents). Moreover, we have analyzed the moderating effect of switching costs.

The study we present evidences, first, that the switching costs do not reduce the effect of predisposing factors in the intent to break a relationship, but do soften the effect of the precipitating factors; and second, that this moderating effect, even if weak, is different in different legal contexts. The effect of the predisposing factors is reduced in Spain when the consumer perceives switching costs, but not in Venezuela. As we have proposed, when the legislation is more stringent and less permissive, the individuals feel that their options are more limited, as far as they need to take out new insurance in case of dissolution. This situation provokes that the inhibitors, i.e. switching costs, become more relevant. It does not occur when the consumers can decide without restraint if they take out insurance or not. In this situation, the switching costs are not a real impediment for the dissolution because the change of supplier is not urgent, and the consumer can postpone it.

On the other hand, even if the difference between countries is weak as it concerns to the moderating effect of switching costs in the precipitating factors, the results obtained are interesting. In general, the switching costs moderate the intent to break as a consequence of an unfair price or an anger incident, however, the legal context (more or less permissive law), has not a significant role in this process.

Another interesting result, which was not part of our hypotheses, refers to the different impact of predisposing and precipitating factors on the intent to break in each legal context. Although the differences between countries are not significant, the results show that the precipitating factors are relatively more important than the predisposing factors in Spain, whereas in Venezuela the situation is inverse. The greater contribution of the unfair price and the anger incidents on the relationship dissolution in Spain can be justified because the consumers are conscious of the existence of a compulsory law and their behaviour is conditioned by this imposition. The sacrifice done because of obligation acquires a greater importance than the obtained benefices, and the consumer will not act with the acquiescence of a consumer that have made a free decision. When the decision is not compulsory, it is said that *he that would have the fruit must climb the tree*. In other words, the monetary sacrifice for something not wanted will be perceived as excessive. Since in Venezuela the consumers are not conscious of the obligation to take out insurance, the importance of price or anger incidents is lower because their commitment with the firm is voluntary, freely decided.

As it concerns to the *managerial implications*, we reinforce the idea of the weak moderating effect of switching costs. It seems that the direct effect of predisposing and precipitating factors in the intent to break is so strong that the barriers of the switching costs are hardly perceptible. Once the predisposing and the precipitating factors achieve a threshold, the perceived switching costs, even if they are high, are not an obstacle to dissolve a relationship, because the costs of maintaining it is greater than the breaking and switching costs. Therefore, we suggest, that the commercial policies that “trap” the consumer with switching barriers are really inefficient when the dissolution process starts. Even if these policies are efficient in order to maintain a loyal consumer when the relationship is beneficial to both parties, its effect is null when the consumer perceives serious problems in the service and decides to break the relationship. Similarly, some authors such as Patterson and Smith (2003) indicate that switching costs can have a boomerang effect for the firm. If customers are unable to easily defect (because of the switching barriers) they may restrict their spending with a focal service provider (Coyles and Gokey, 2002).

Moreover, we suggest that the firms should know the cultural and legal context of each country as far as it has an influence on the consumer’s perception of the firm’s activities. When the legal context allows the consumer to be free when making decisions, the positive factors, that is, the benefices he/she receives such as the quality and the firm’s commitment, have greater importance in he/she decision than when the consumer is bound by the legislation. On the contrary, the negative factors, that is, the compensation he/she gives, such as the price and the incidents, are more relevant for those consumers who perceive the transaction as a legal obligation.

One of the *limitations of this work* is the use of transversal data. Longitudinal data should have been considered in order to explore the impact of the different factors on dissolution over time. These data would enable us to examine the real consumer exit and switch behaviour and determine when the switching costs act as an attenuating factor on exit behaviour.

The work has not explored which other cultural features of a country may impact behaviour and intention, beyond mere law enforcement. Although the link between this area and some of a country’s cultural dimensions proposed by Hofstede has already been posited, it would no doubt prove enlightening to include in future work other cultural and commercial aspects along the lines put forward by Zhang *et al* (2007), such as the relationship forged between client and provider or consumer habits as regards making complaints to firms.

Finally, in this work, we have analyzed the perception of legal obligation, but we have not considered the perception of moral obligation. This distinction could justify why some of the differences between the two contexts are lower than we have expected.

REFERENCES

- Albers, S. & Hildebrandt, L. (2006). Methodische Probleme bei der Erfolgsfaktorenforschung Messfehler, formative versus reflective Indikatoren und die Wahl des Strukturgleichungs-Modells. *Zfbf*, 58, 2–33.
- Anderson, E. & Weitz, B. (1992). The use of pledges to built and sustain commitment in distribution channels. *Journal of Marketing Research*, 29 (1), 18–34.

- Anonymous, (1988). Why auto insurance is sometimes compulsory. *Journal of American Insurance*, 64 (Third Quarter), 8-12.
- Antón, C., Camarero, C. & Carrero, M. (2007). The mediating effect of satisfaction on consumers' switching intention. *Psychology & Marketing*, 24 (6), 511-538.
- Athanassopoulous, A.D. (2000). Customer satisfaction cues to support market segmentation and explain switching behavior. *Journal of Business Research*, 47 (3), 191-207.
- Bansal, H.S. & Taylor, S.F. (1999). The service provider switching model (SPSM). A model of consumer switching behavior in the services industries. *Journal of Service Research*, 2 (2), 200-218.
- Bansal, H.S. & Taylor, S.F. (2002). Investigating interactive effects in the theory of planned behavior in a service-provider switching context. *Psychology & Marketing*, 19 (5), 407-425.
- Bansal, H.S., Taylor, S.F. & James, Y.S. (2005). Migrating' to new service providers: toward a unifying framework of consumers' switching behavior. *Journal of the Academy of Marketing Science*, 33 (1), 96-115.
- Berry, L. (1995). Relationship marketing of services - Growing interest, emerging perspectives. *Journal of the Academy of Marketing Science*, 23, 236-245.
- Bougie, R., Pieters, R. & Zeelenberg, M. (2003). Angry customers don't come back, they get back: the experience and behavioral implications of anger and dissatisfaction in services. *Journal of the Academy of Marketing Science*, 31 (4) 377-393.
- Brady, M. & Cronin, J. (2001). Some new thoughts on conceptualizing perceived service quality: a hierarchical approach. *Journal of Marketing*, 61 (1), 34-49.
- Burnham A., Frels, J.K. & Majahan, V. (2003). Consumer Switching cost: A Typology, Antecedents, and Consequences. *Journal of the Academy of Marketing Science*, 31 (2), 109-126.
- Campbell, M.C. (1999). Perceptions of price unfairness: antecedents and consequences. *Journal of Marketing Research*. 36, 187-199.
- Castelo, M.L. (2006). El seguro de automóviles en iberoamérica [online]. Instituto de Ciencias del Seguro, Fundación Mafre. Available from: <http://www.fundacionmapfre.com/cienciasdelseguro>. [Accessed 30 December 2007].
- Castiglione, S. (2004). Lesiones no intencionales. Legislación de América Latina sobre programas preventivos y responsabilidades. Colisión y atropello por vehículos, caídas, quemaduras y ahogamientos. Washington, D.C.: Organización Panamericana de la Salud.
- Chin, W., Marcolin, B. L. & Newsted, P. R. (1996). A partial least squares latent variable modeling approach for measuring interaction effects: results from a Monte Carlo simulation study and voice mail emotion/adoption study. *Proceedings of the Seventeenth International Conference on Information Systems, Cleveland, Ohio*.
- Chin, W. (1998). The partial least square approach for structural equation modeling. In G.A. Marcoulides, (Ed.), *Modern methods for business research* (pp. 295-336). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Chin, W. & Newsted P.R. (1999). Structural equation modeling analysis with small samples using partial least squares. In R. Hoyle, (Ed), *Statistical strategies for small samples research* (pp. 307-341). Thousand Oaks, California: Sage Publications.
- Chin, W. (2005). Partial least squares SEM with PLS-Graph: demonstration with examples from marketing & IT research. C.T. Bauer College of Business University of Houston.

- Available from: <http://www.bauer.uh.edu/plsgraph/chinpls2005.pdf> [Accessed 30 December 2007].
- Coyles, S. & Gokey, T. C. (2002). Customers retention is not enough. *The McKinsey Quarterly*, (Spring), 1–6.
- Cronin, J.J. & Taylor, S.A. (1992). Measuring service quality. A reexamination and extension. *Journal of Marketing*, 56 (July), 55–68.
- Dabholkar, P.A. & Walls, S. (1999). Service evaluation and switching behaviour for experiential services: an empirical test of gender differences within a broader conceptual framework. *Journal of Consumer Satisfaction, Dissatisfaction, and Complaining Behaviour*, 12, 123–137.
- Diamantopoulos A, & Winklhofer, H. M. (2001). Index construction with formative indicators. *Journal of Marketing Research*, 38, 269–77.
- Dodds, W.B., Monroe, K.B. & Grewal, D. (1991). The effects of price, brand, and store information on buyer's product evaluations. *Journal of Marketing Research*, 28, 307–319.
- Duck, S. (1981). Toward a research map for the study of relationship breakdown. Duck, S. and Gilmour R., *Personal Relationships 3: Personal Relationships in Disorder* (pp. 1–29). London: Academic Press.
- Duck, S. (1982). A topography of relationship disengagement and dissolution. In Duck, S (Ed.), *Personal Relationships 4: Dissolving personal relationships* (pp. 1–30). London: Academic Press.
- Durvasula, S, Lysonski, S. & Watson, J. (2001). Does vanity describe other cultures? A cross-cultural examination of the vanity scale. *Journal of Consumer Affaires*, 35, 180–99.
- Dwyer, R., Schurr, P. & Oh, S. (1987). Developing buyer-seller relationships. *Journal of Marketing*, 51 (April), 11–27.
- Grönroos, C. (1990). *Service management and marketing*. Lexington, MA: D.C. Heath & Co.
- Gundlach, G. & Cadotte, E. (1995). Exchange interdependence and interfirm interaction: research in a simulated channel setting. *Journal of Marketing Research*, 31 (November), 516–32.
- Halinen, A. & Tähtinen, J. (2002). A process theory of relationship ending, *International Journal of Service Industry Management*, 13 (2), 163–180.
- Halinen, A., Havila, V. & Salmi, A. (1999). From dyadic change to changing networks: an analytical framework. *Journal of Management Studies*, 36, 6, 779–794.
- Hellier, P.K., Geursen, G.M., Carr, R.A. & Rickard, J.A. (2003). Customer repurchase intention. A general structural equation model. *European Journal of Marketing*, 37 (11/12), 1762–1800.
- Hess, M.J. & Ricart, J.E. (2003). Managing Customer Switching Costs: A Framework for Competing in the Networked Environment. *Management Research*, 1 (1), 93–110.
- Hess, R.L., Ganesan, S. & Klein, N.M. (2003). Service Failure and Recovery: The impact of relationship factor on customer satisfaction. *Journal of the Academy of Marketing Science*, 31 (2), 127–147.
- Hocutt, M.A. (1998). Relationship dissolution model: antecedents of relationship commitment and the likelihood of dissolving a relationship. *International Journal of Service Industry Management*, 9 (2), 189–200.
- Hofstede, Geert (2001). *Culture's consequences*. (2nd ed.), Sage, Thousand Oaks, CA.

- Homburg, C., Hoyer, W.D. & Koschate, N. (2005). Customers' reactions to price increases: do customer satisfaction and perceived motive fairness matter? *Journal of the Academy of Marketing Science*, 33, 36-49.
- Jones, M.A., Mothersbaugh, D.L. & Beatty, S.E. (2000). Switching barriers and purchase intentions in services. *Journal of Retailing*, 76 (2), 259-274.
- Keaveney, S. M. (1995). Customer switching behavior in service industries: An exploratory study, *Journal of Marketing*, 59 (2), 71-82.
- Keaveney, S.M. & Parthasarathy (2001). Customer switching behavior in online services: an exploratory study of the role of selected attitudinal, behavioral, and demographic factors. *Journal of the Academy of Marketing Science*, 29 (4), 374-390.
- Kelley, S.W.K. & Davis, M.A. (1994). Antecedents to customer expectations for service recovery. *Journal of the Academy of Marketing Science*, 22, 52-61.
- Kirmani, A. & Rao, A. (2000). No pain, no gain: a critical review of the literature on signaling unobservable product quality. *Journal of Marketing*, 64, 66-79.
- Kumar, N., Scheer, L. & Steenkamp, J.B. (1995a). The effects of supplier fairness on vulnerable resellers. *Journal of Marketing Research*, 32 (1), 54-65.
- Kumar, N., Scheer, L. & Steenkamp, J.B. (1995b). The effects of perceived interdependence on dealer attitudes. *Journal of Marketing Research*, 32 (August), 348-56.
- Lee, J., Lee, J. & Feick, L. (2001). The Impact of Switching Costs on the Customer Satisfaction-Loyalty Link: Mobile Phone Service in France. *Journal of Services Marketing*, 15 (1), 35-48.
- Maurer, T., Raju, N. & Collins, W.C. (1998). Peer and subordinate appraisal measurement equivalence. *Journal of Applied Psychology*, 83, 693- 702.
- Michalski, S. (2004). Types of customer relationship ending processes. *Journal of Marketing Management*, 20, 977-999.
- Mittal, B. & Lassar, W. (1998). Why do customers switch? The dynamics of satisfaction versus loyalty. *The Journal of Services Marketing*, 12 (3), 177-194.
- Mohr, J.J. & Spekman, R. (1994). Characteristics of partnership success: partnership attributes, communication behavior, and conflict resolution techniques. *Strategic Management Journal*, 15, 135-52.
- Morgan, R. & Hunt, S., (1994). The commitment-trust theory of the relationship marketing. *Journal of Marketing*, 58, 20-38.
- Oliva, T.A., Olivier, R.L. & MacMillan, I.C. (1992). A catastrophe model for developing service satisfaction strategies. *Journal of Marketing*, 56 (3), 83-95.
- Parasuman, A., Zeithaml, V.A. & Berry, L.L. (1988). SERVQUAL: a multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing*, 64, pp.12-40.
- Paterson, P. G. & Smith, T. (2003). A cross-cultural study of switching barriers and propensity stay with service providers. *Journal of Retailing*, 79, 107-120.
- Ping, R.A. (1994). Does satisfaction moderate the association between alternative attractiveness and exist intention in a marketing channel? *Journal of the Academy of Marketing Science*, 22, (4), 364-371.
- Ping, R. (1995). Some uninvestigated antecedents of retailer exit intention. *Journal of Business Research*, 34, 171-180.
- Ringle, C. M., Wende, S. & Will A. (2005). SmartPLS 2.0 (beta). Available from: <http://www.smartpls.de>.

- Roos, I. (1999). Switching processes in customer relationships. *Journal of Service Research*, 2 (1), 68-85.
- Roos, I. (2002). Methods of investigating critical incidents. *Journal of Service Research*, 4 (3), 193-204.
- Roseman, I.J., Wiest, C.M.S. & Swartz, T.S. (1994). Phenomenology, behaviors, and goals differentiate discrete emotions. *Journal of Personality and Social Psychology*, 67, 206-211.
- Rusbult, C., Zembroke, I. & Gunn, L. (1983). Exit, voice, loyalty and neglect: responses to dissatisfaction in romantic involvements. *Journal of Personality and Social Psychology*, 43, 1230-1242.
- Sharma, N. & Patterson, P.G. (2000). Switching costs, alternative attractiveness and experience as moderators of relationship commitment in professional consumer services. *International Journal of Service Industry Management*, 11 (5), 470-90.
- Sheth, J. N. & Parvatiyar, A. (1995). Relationship marketing in consumer markets: antecedents and consequences. *Journal of the Academy of Marketing Science*, 23 (4), 255-271.
- Steenkamp, J.B. & Baumgartner, H. (1998). Assessing measurement invariance in crossnational consumer research. *Journal of Consumer Research*, 25, 78-90.
- Tähtinen, J. & Vaaland, T.I. (2006). Business relationships facing the end: why restore them? *Journal of Business & Industrial Marketing*, 21 (1), 14-23.
- Teas, R.K. & Agarwal, S. (2000). The effects of extrinsic product cues on consumers' perceptions of quality, sacrifice, and value. *Journal of the Academy of Marketing Science*, 28, 278-290.
- Wathne, K., Biong, H. & Heide, J.B. (2001). Choice of supplier in embedded markets: relationship and marketing program effects. *Journal of Marketing*, 65, 54-66.
- Zeithaml, V.A., Berry, L.L. & Parasuraman, A. (1996). The behavioural consequences of service quality. *Journal of Marketing*, 60, 31-46.
- Zhang, J., Beatty, S. & Walsh, G. (2007). Review and future directions of cross-cultural consumer services research. *Journal of Business Research*, in press.

Chapter 16

TRIPARTITE CONCEPTS OF MIND AND BRAIN, WITH SPECIAL EMPHASIS ON THE NEUROEVOLUTIONARY POSTULATES OF CHRISTFRIED JAKOB AND PAUL MACLEAN

Lazaros C. Triarhou*

Economo–Koskinas Wing for Integrative and Evolutionary Neuroscience,
University of Macedonia, Thessaloniki, Greece

ABSTRACT

The ‘triune brain’, conceived by Paul D. MacLean (1913–2007) in the late 1960s, has witnessed more attention and controversy than any other evolutionary model of brain and behavior in modern neuroscience. Decades earlier, in his book *Elements of Neurobiology* published in 1923 in La Plata, Argentina, neurobiologist Christfried (Christofredo) Jakob (1866–1956) had formulated a ‘tripsychic’ brain system, based on his deep understanding of biological and neural phylogeny. In a historical context, 1923 was also the year of publication of Sigmund Freud’s *The Ego and the Id*, whereby the founder of psychoanalysis solidified his tripartite model of the mental apparatus. Tripartite systems of the human mind have been surmised since Plato and Aristotle; they continue to our era, an example being Robert J. Sternberg’s triarchic theory of human intelligence. In view of the fact that both Jakob and MacLean invested a considerable part of their long and distinguished careers studying comparative, and particularly reptilian neurobiology, the present article revisits their neuroevolutionary models, underlining the convergence of their anatomical-functional propositions, in spite of a time distance of almost half a century.

* E-mail address: triarhou@uom.gr, phone +30 2310 891-387, fax +30 2310 891-388

INTRODUCTION

In the words of neurologist William E. DeMyer [1], “to understand the brain–thought–behavior triumvirate is the Holy Grail of neuroanatomy, as compelling to the researcher as a cyclonic vortex.” Models to explain the mechanisms of operation of the human mental apparatus have been formulated since the era of classical Greece. The preponderance of such models appear to be ‘tripartite,’ without necessarily entailing that e.g. unipartite, bipartite or quintopartite models would be less meaningful.



Figure 1. Left: Portrait of Paul D. MacLean (1913–2007), taken in 2001 by Kelly G. Lambert [81] © 2003 Elsevier Inc., reproduced with permission; signature from the author’s private archive. Right: Portrait of Christofredo Jakob (1866–1956), from Orlando’s book cover [15]; signature from Jakob’s 1924 notes of pathological anatomy and physiology (full reference in [17]), courtesy of Staatsbibliothek Berlin.

The ‘triune brain’, conceived by neurobiologist-psychiatrist Paul D. MacLean (1913–2007) (Fig. 1), has been popularized way beyond the neurosciences. This becomes evident in the treatments by Arthur Koestler in chapter 16 (‘The three brains’) of his *Ghosts in the Machine* [2] – the concluding sequel of the trilogy which includes the 1959 *Sleepwalkers: A History of Man’s Changing Vision of the Universe* and the 1964 *Act of Creation* –, and by Carl Sagan in chapter 3 (‘The brain and the chariot’) of his evolutionary saga *The Dragons of Eden* [3]. Further, the triune brain featured in a documentary produced by the National Film Board of Canada [4]. In recent years, the triune modular brain concept has been accommodated by the social sciences: Cory [5] suggested an extended dynamic model of neural social architecture, the ‘conflict systems neurobehavioral’ (CSN) model, placing more emphasis on behavioral than on neurological terms.

Concerning neuroanatomical terminology, Elliot Smith [6] coined the term *neopallium* in 1901 to denote a cortical organ that had the ability, based on progressive evolution, to learn with experience through a mechanism of sensory perception, associative memory, consciousness and response (Figure 2). Elliot Smith [7 (pp. 31–38)] regarded the neopallium as fulfilling all the conditions of the Aristotelian *sensorium commune*.

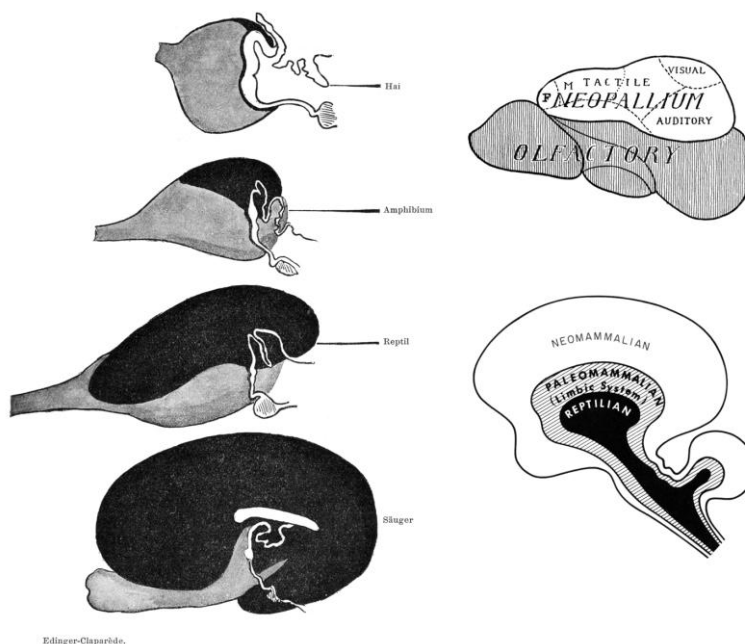


Figure 2. *Left column*: The first original idea of 1908, credited to Edinger, suggesting the evolutionary distinction of the brain into an 'old' (gray) and a 'new' part (black). The drawing depicts, top to bottom, the brains of a shark, an amphibian, a reptile and a mammal. The *palaeöencephalon* exists from insects to man, and remains virtually unchanged from shark to elephant. The *neöencephalon* made its first appearance in fish and progressed all the way to humans, filling the entire skull. From figure 8 in Edinger [11 (p. 17)]. *Upper right*: Sir Grafton Elliot Smith introduced the term neopallium in 1901. The diagram shows the lateral aspect of the left cerebral hemisphere of a primitive mammal, the jumping shrew (*Macroscelides*), and the relatively enormous extent of the primitive olfactory territories and small neopallium with its receptive areas for tactile, visual and auditory impressions. The anterior segment of the tactile area (from *M* back to the dotted line) represents the so-called 'motor area'. *F* represents the frontal area rudiment. From figure 7 in Elliot Smith [7 (p. 33)]. *Lower right*: Schematic representation of the theorized hierarchical organization in the triune brain concept of MacLean [73, 75]. The three basic components, in an ascending evolutionary order, are the *reptilian complex*, the *limbic system* (paleomammalian brain), and the *neocortex* (neomammalian brain), roughly subserving *instincts*, *emotions*, and *intellect*, respectively.

The designations 'paleo-', 'archi-' and 'neo-' for the cortex (pallium) on grounds of their sequential evolutionary appearance were introduced with a 1909 paper of Ariëns Kappers [8],¹ which subsequently led to similar designations for diverse brain regions, including the striatum, thalamus and cerebellum [10]. Kappers' mentor, Frankfurt anatomist Ludwig Edinger [11] had provided the fundamental intellectual stimulus the previous year, 1908, by systematizing the brain into *palaeöencephalon*, the highly conserved midbrain and hindbrain, and *neöencephalon*, the forebrain, which varies substantially among vertebrates, appearing for the first time in fish and increasing in size and complexity along the phylogenetic scale (Figure 2).

¹ In a footnote, Jakob [9 (p. 12)] argues that, to avoid confusion by various authors, the correct chronological order of the three terms on etymological grounds should be archi-, paleo- and neo-, since ἀρχή means origin or beginning, and should therefore precede παλαιός, which means old or ancient.

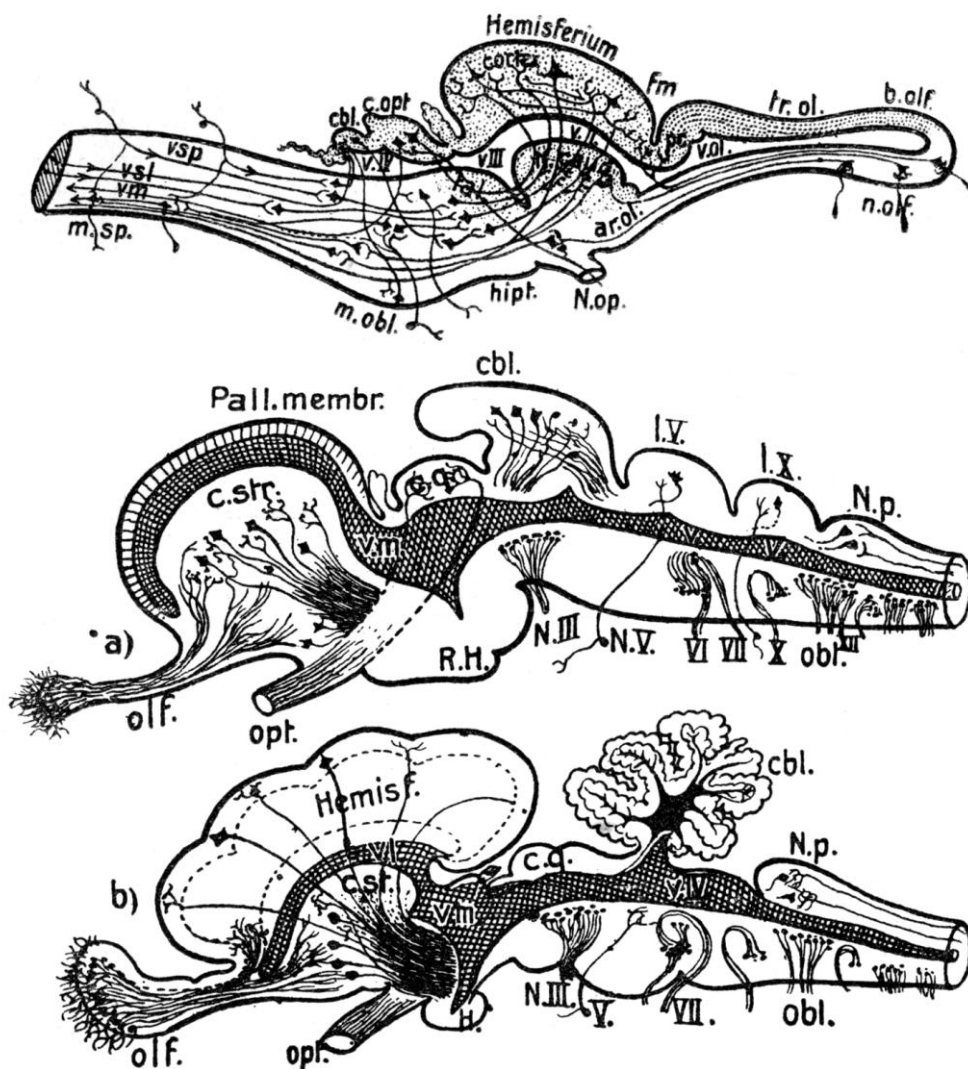


Figure 3. Sagittal schematic views of reflex and central nervous pathways in the brain of a reptile (top), a fish or 'lower vertebrate' (middle) and a mammal or 'higher vertebrate' (bottom). The atlases of comparative neuroanatomy by Jakob and Onelli [21, 22] are rare treasures of evolutionary information. In them, the anatomical properties and connections patterns of cortical (monostriated to polystriated), striatal, hypothalamic and mesencephalic structures, among others, are related from fish through reptiles to primates, as are the underlying functional correlations. Sources: top frame is from figure 7 on p. 8 in [21], also appearing on p. 13 in [22]; middle and bottom frames are from figure 1 on p. 6 in [21], also appearing on p. 11 in [22] and in figure 13 on p. 32 in [66]. Note that in the top frame the olfactory bulb is oriented to the right side; in the middle and bottom frames to the left.

Edinger's core proposition, i.e. that the forebrain has evolved through a sequential addition of parts, is most likely the original idea from which MacLean's 'triune brain' concept derives [12 (p. 31)]. Tilney [13] used the term *archikinetic* to connote balance functions subserved by the medial group of the deep cerebellar nuclei (globose and fastigial), and *neokinetic* for the skilled movements of the face and limbs subserved by the lateral group

Some of the most pertinent contributions to a neuroevolutionary approach of behavior have come from Christfried (Christofredo) Jakob (1866–1956) (Fig. 1), a German-born neuropathologist who spent most of his professional life in Argentina. Having studied under Friedrich Albert von Zenker (1825–1898) and Adolf von Strümpell (1853–1925) at Erlangen, Jakob subsequently became affiliated with the National Universities of La Plata and of Buenos Aires, where he established one of the most important neuropathological laboratories in South America. He is considered the father of Argentinian neurobiology and forensic histopathology and has left an invaluable legacy of 200 articles and 30 monographs in German and Spanish [15–17]. Jakob reached international renown through his early successful handbooks of clinical medicine [18] and neurology [19], as well as his atlases of human [20] and comparative neuroanatomy [21, 22] (Figures 3 and 4).

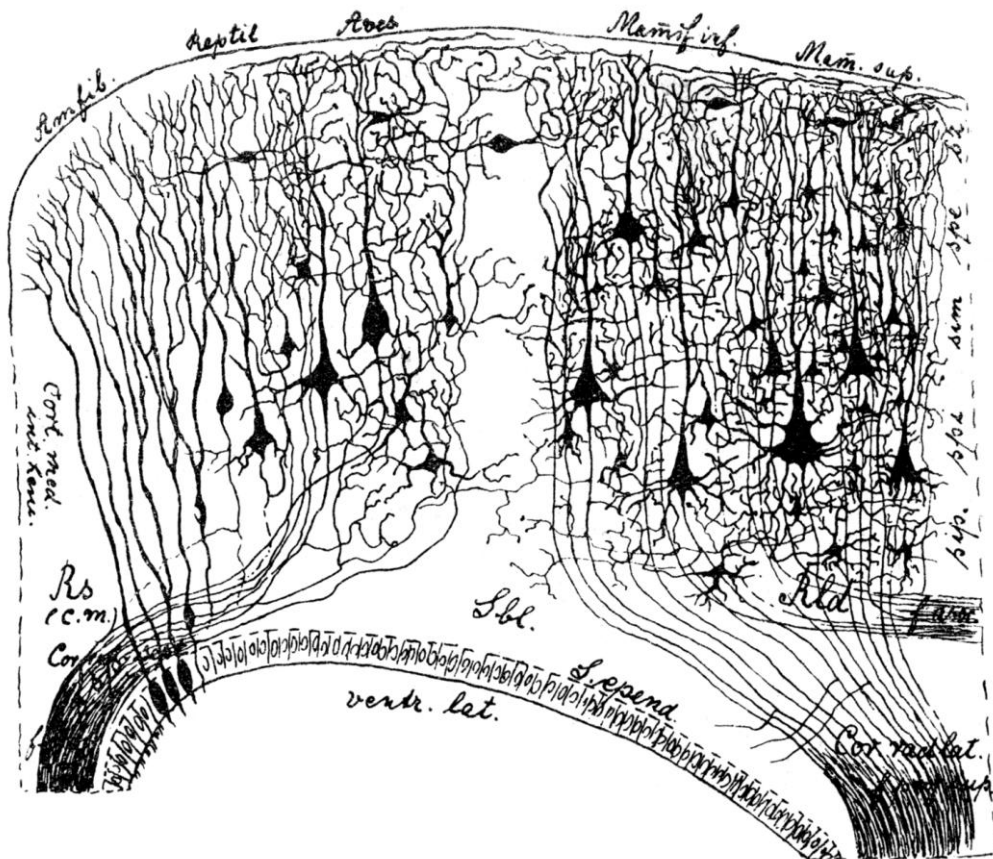


Figure 4. Phylogenetic evolution of the cerebral cortex from monostratified to polystratified. From left to right, amphibian, reptilian, avian, mammalian, and higher mammalian cortical layer structure. Source: from figure 32 on p. 23 in [21], also appearing on p. 16 in [22].

Some of the most pertinent contributions to a neuroevolutionary approach of behavior have come from Christfried (Christofredo) Jakob (1866–1956) (Fig. 1), a German-born neuropathologist who spent most of his professional life in Argentina. Having studied under Friedrich Albert von Zenker (1825–1898) and Adolf von Strümpell (1853–1925) at Erlangen, Jakob subsequently became affiliated with the National Universities of La Plata and of Buenos Aires, where he established one of the most important neuropathological laboratories in South America. He is considered the father of Argentinian neurobiology and forensic histopathology and has left an invaluable legacy of 200 articles and 30 monographs in German and Spanish [15–17]. Jakob reached international renown through his early successful handbooks of clinical medicine [18] and neurology [19], as well as his atlases of human [20] and comparative neuroanatomy [21, 22] (Figures 3 and 4).

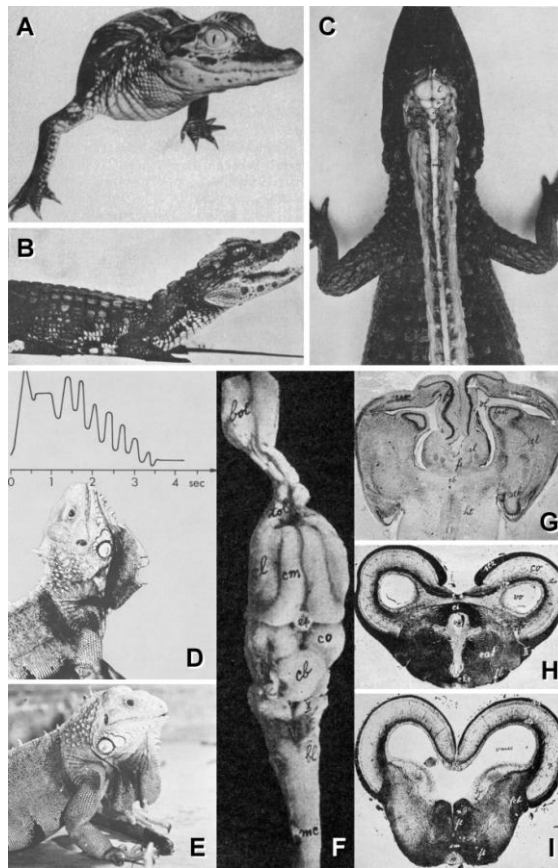


Figure 5. (A) A young alligator used for studies on temperature regulation and reproductive behavior at MacLean's Laboratory of Brain Evolution and Behavior at the National Institute of Mental Health [97]. (B) The yacaré (*Caiman latirostris*) displaying the innate 'terrorizing' reflex posture, an 'archineuronal brainstem reaction' [53 (p. 143)]. (C) Brain and spinal cord of a young yacaré ('alligator of Chaco') dissected in situ. One can discern the cerebral hemispheres, optic tectum, small cerebellum, and the dorsal medulla and spinal cord. From plate 37a in [9 (p. 97)]. (D, E) Onset and termination of a stereotypic 'head-nodding' behavior displayed by a male *Iguana iguana* lizard from South America; this type of fixed social signal may have evolved 150 million years ago. From work by MacLean's alumnus Detlev Ploog [100]. (F) Dorsal view of the iguana brain. The Ammonic zone or medial cortical (*cm*) and lateral cortical (*cl*) portion of the cerebral hemispheres can be seen, separated by the dorsal longitudinal lateral sulcus, which is the precursor of the hippocampal sulcus. *Abbreviations:* *bol*, olfactory bulb; *tol*, olfactory tubercle; *ep*, epiphysis (pineal); *co*, optic tectum; *cb*, cerebellum; *X*, vagus; *bl*, medulla oblongata; *mc*, spinal cord. From figure 86 in [9 (p. 136)]. (G) Coronal section of the anterior cerebrum of *Iguana iguana*, at the level of the basal commissure (*cb*) and its continuation towards the hypothalamus. Between the fascia dentata and Ammon's zone, the lateral sulcal depression is found. From figure 87 in [9 (p. 138)]. (H) The midbrain of *Iguana iguana*. Entry of the optic nerve (*II*) in the zonal layer (*stz*); superior (*cs*) and inferior (*ci*) mesencephalic commissure in the tectum; at the bottom is the hypothalamic commissure (*cht*). Weigert stain, $\times 50$. From figure 94 in [9 (p. 150)]. (I) Coronal section through the midbrain of *Iguana iguana*, showing the three layers of the optic body, the zonal (*sz*), the intermediate, and the deep (*stp*), as well as its commissure (*cc*). Laterally the optic bundle (*II*) enters into the zonal layer. From the deep layer derives the bulbar quadrigeminal descending fasciculus (*fb*) also called by various authors tectospinal. In the ventral half one can distinguish the posterior longitudinal fasciculus (*fl*), the reticular formation and the basal (striodiencephalobulbar) fasciculus. Weigert stain, $\times 90$. From plate XXXVIIa in [9 (p. 95)].

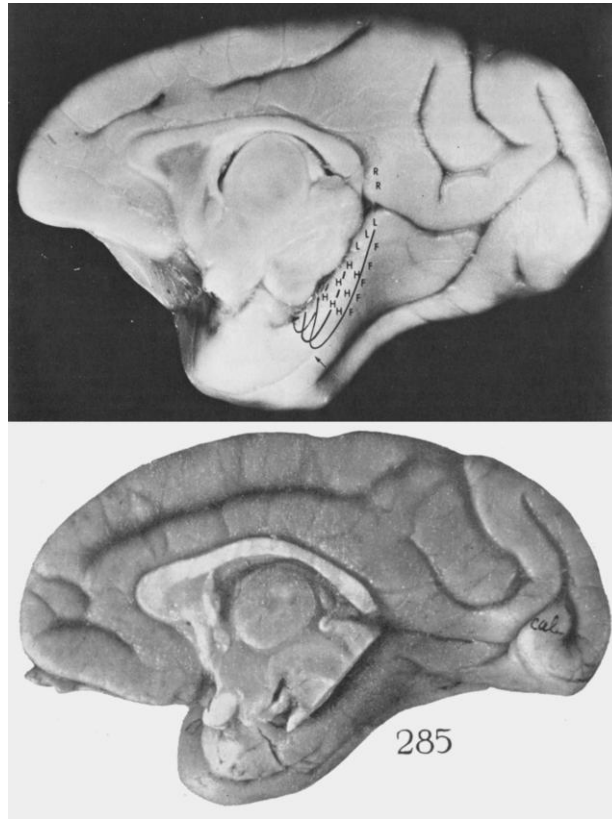


Figure 6. *Upper*: Median facies of the brain of a squirrel monkey to show the approximate location of light-responsive areas. *Abbreviations*: *H*, posterior hippocampal gyrus; *L*, parahippoampal portion of lingual gyrus; *R*, retrosplenial cortex; *F*, fusiform gyrus. Arrow shows the caudal extreme of rhinal sulcus at the caudal limit of the entorhinal area. From figure 5 in [75 (p. 343)]. *Lower*: Macroscopic brain specimen of a cebus monkey from Paraguay. From plate LXII in [22].

He later produced landmark works on evolutionary neurobiology, studying in detail dozens of species of the autochthonous Patagonian fauna, including the broad-snouted ‘yacaré’ (or *Caiman latirostris*), a reptile of the Alligatoridae family [23], and the ‘pichiciego’ (fairy armadillo or *Chlamyphorus truncatus*), a mammal of the Dasypodidae family [24].

The aim of the present article is first, to revitalize an interest in the evolutionary concepts of Christofredo Jakob, a foremost neuroanatomist of the 20th century and perhaps one of the earliest pioneers in neurophilosophy; and second, to pinpoint the confluences between the anatomical-functional conceptions of Jakob and MacLean regarding their tripartite models of the human mind based on evolutionary criteria, despite a time distance of almost half a century. For a broader perspective, certain other tripartite models of the human mind from the classical antiquity through present are mentioned.

Both Jakob and MacLean invested a considerable part of their long and distinguished careers studying comparative neurobiology from reptiles (Fig. 5) to primates (Fig. 6), and both left their mark on scientific advances regarding the visceral and olfactory brain and the limbic system (Figure 7). As a matter of fact, there is a whole line of evidence indicating that Jakob described the anatomical elements of the visceral brain some 30 years before the widely known ‘circuit of Papez’ came into being [25–31]. On the other hand, MacLean’s

contributions have been instrumental in both defining the limbic system and in sorting out some of its key emotional functions in normality and psychopathology [32–38].

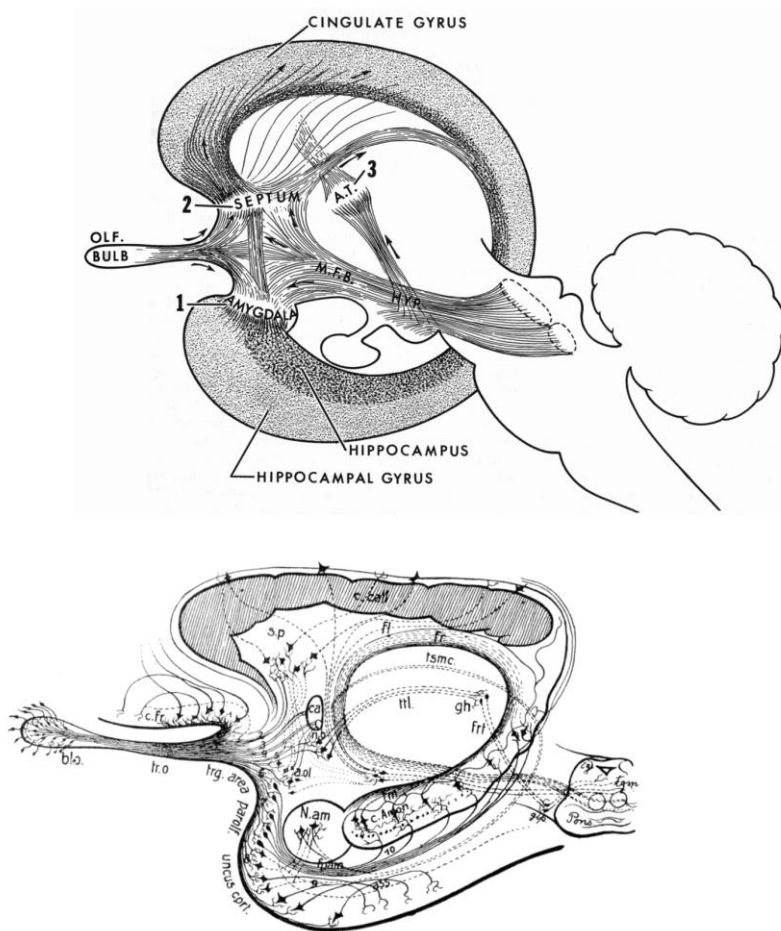


Figure 7. Drawings of the limbic system and the rhinencephalon (olfactory brain) by MacLean [75] and Jakob [20]. *Upper*: Limbic cortex and its connections with brainstem structures. *Abbreviations*: A.T., anterior thalamic nuclei; HYP, hypothalamus; M.F.B., median forebrain bundle; OLF, olfactory [75 (figure 4 on p. 341)]. *Lower*: The rhinencephalon and the olfactory radiation, with the anatomical connections of the olfactory bulb, septum, anterior commissure and uncus hippocampi [20 (figure 15 on p. 19)].

PHILOSOPHICAL TRIPARTITE MODELS OF THE PSYCHE

Plato of Athens developed a tripartite concept of the human psyche in *Phaedrus* (370 B.C.) and in the *Republic* (360 B.C.). For him, the cerebrospinal marrow is the organic seat of the ‘rational’ or ‘intelligent’ (λογιστικόν), the ‘temperamental’ or ‘courageous’ (θυμοειδές), and the passionate or appetitive (ἐπιθυμητικόν), respectively occupying the cerebral, thoracic, and abdominal portion [39 (pp. 270–271), 40, 41]. Atomic philosopher Democritus of Abdera

(c. 460–370 B.C.) may have anticipated Plato's tripartite division of the psyche [39 (pp. 254–255)], naming the brain the 'guard of the mind' (φύλαξ διανοίας), the heart the 'control of passion' (ὀργῆς τιθηνός), and the liver the 'cause of desire' (ἐπιθυμίας αἴτιον).

Burnet [42 (p. 149)] argues that the doctrine of the tripartite psyche was in reality Pythagorean. Among existing suggestions at the time, Plato adopted in *Timaeus* (360 B.C.) the landmark discovery made by Alcmaeon of Croton (500 B.C.) that the brain is the faculty of the mind [43]. Based on that thesis, Socrates speculates in *Phaedo* that the brain provides sensations (αἰσθήσεις); from these arise memory (μνήμη) and opinion (δόξα); and when stabilized, these become knowledge (ἐπιστήμη) [39 (p. 269)].

Cohen [44] surmises that, because the Bible makes God tripartite with the three persons of the Trinity and teaches that man is made in God's image, theologians have looked for a Biblical tripartite nomenclature for man: a unified totality, comprising the components of 'spirit' (πνεῦμα), 'psyche' (ψυχή), and 'body' (σῶμα), the only Biblical support for a doctrine of human tripartiteness found in the First Epistle to the Thessalonians (ε' 23).

A noteworthy association from the domain of classical drama – not far from neuroscience in an essential way² – is a metaphorical tripartite model of the human psyche discerned in the Karamazov brothers of Fyodor Dostoyevsky's 1880 crowning success, Dmitri representing 'passion', Ivan 'intellect', and Alyosha 'contemplation' [46].

THE TRIPSYCHIC BRAIN SYSTEM OF JAKOB

In his 1923 *Elements of Neurobiology*, Jakob establishes three categories of 'neurodynamic' functions [47 (pp. 197–209)]:

- (1) *plasmopsychisms* or *plasmodynamisms* (tropism, taxism, and pulsatile rhythms);
- (2) *phylopsychisms* or *neurodynamisms* (simple serial or organized reflexes, otherwise instincts); and
- (3) *ontopsychisms* or *psychodynamisms* ('gnosias', 'praxias' and 'symbolias').

Jakob [48] viewed motor and sensory elements and their connections as constituting a unit and a fundamental functional cortical arc that forms the basis of psychological phenomena. In the phylogenetic scale, *plasmopsychic* or *plasmodynamic* activities precede all other nervous functions [9].

The above three neurodynamic graduations are all primarily 'biophylactic', i.e. they serve to preserve life, respectively, at its fundamental, the species, and the organism levels [47]. They are found in varying distribution and combination among actual living beings: in the world of plants, as well as in protozoans and sponges one finds only *plasmopsychisms*; in metazoans with ganglionic nervous systems (e.g. hydropolyps, worms, molluscs and arthropods) through the inferior vertebrates (cyclostomes and fish) exist both *plasmopsychisms* and *phylopsychisms*; insects, having a cerebral ganglion, and fish, with their mesencephalon, might potentially exercise elemental *ontopsychic* functions; in amphibians

through the higher vertebrates, including humans, one finds all three categories amalgamated and combined, with a predominance of the *ontopsychic dynamism*, which in humans has culminated into the symbolic psychisms (the elements of the intellectual world, of aesthetics and ethics), without though diminishing the concomitant existence of the more elemental levels.

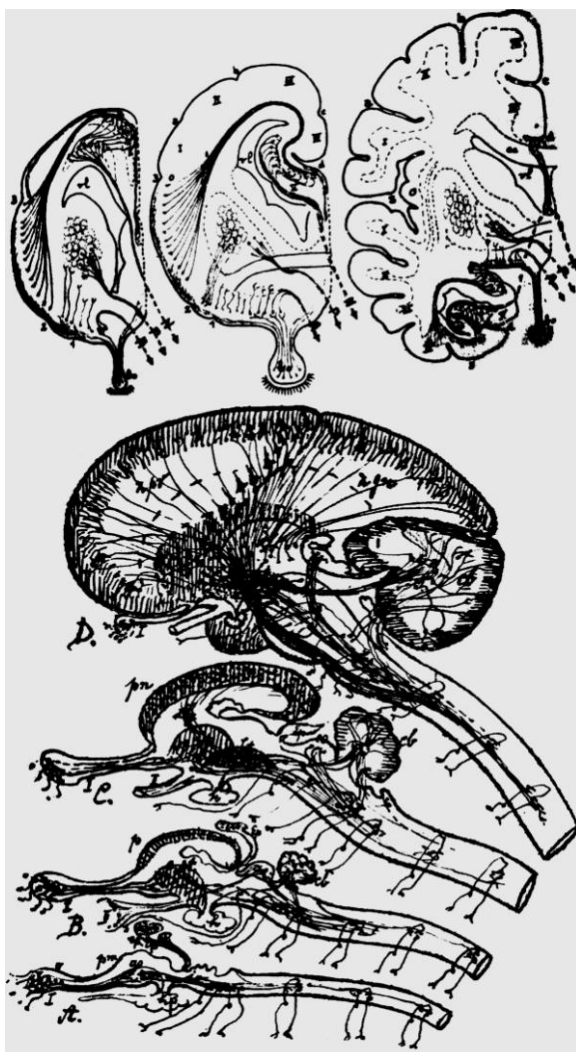


Figure 8. *Upper row*: Schematic drawing of the phylogeny of archineuronal, paleoneuronal and neoneuronal olfactory systems in a reptile (*left*), a marsupial (*center*) and a primate (*right*). From figure 110 in *El Yacaré* [23 (p. 100)]. *Lower group*: Schematic drawing of primordial neural (A), archineural (B), paleoneural (C) and neoneural (D) systems. From *The Neocortex, its Organization and Dynamism* [96 (plate 2)].

² As highlighted by Steven Pinker [45], Dostoyevsky was not foreign to the nervous underpinnings of behavior. In his prison cell, prompted by a visit by the academician Rakitin, Dmitri Karamazov mulls over the fact that thinking results from quivering nerve tails and the chemistry inside the brain, rather than an immaterial soul.

There are three underlying structural-functional hierarchical levels of the nervous system, designated as (a) *archineuronal*, (b) *paleoneuronal* and (c) *neoneuronal* (Fig. 8). *Archineuronal* and *paleoneuronal* levels are inherited³ and constitute the substrate of *phylopsychic* or *neurodynamic* processes; the *neoneuronal* level subserves *ontopsychic* or *psychodynamic* processes, where individual experience becomes possible, and where the will resides [47, 50, 51 (pp. 18–30)].

The *archineuronal* system has a reflex function similar to the invertebrates, comprising simple visceral and somatic reflex arcs ('archikinesias') (Fig. 9, 10A). The *paleoneuronal* system hosts instinctive-automated reactions ('paleokinesias') and it becomes able to prolong the effects of stimuli over time, thus instigating a *chronotropic* ability (Fig. 9). Examples of paleokinetic systems [50, 52] can be found in the cerebellum and the corpus striatum (Fig. 10B, C).

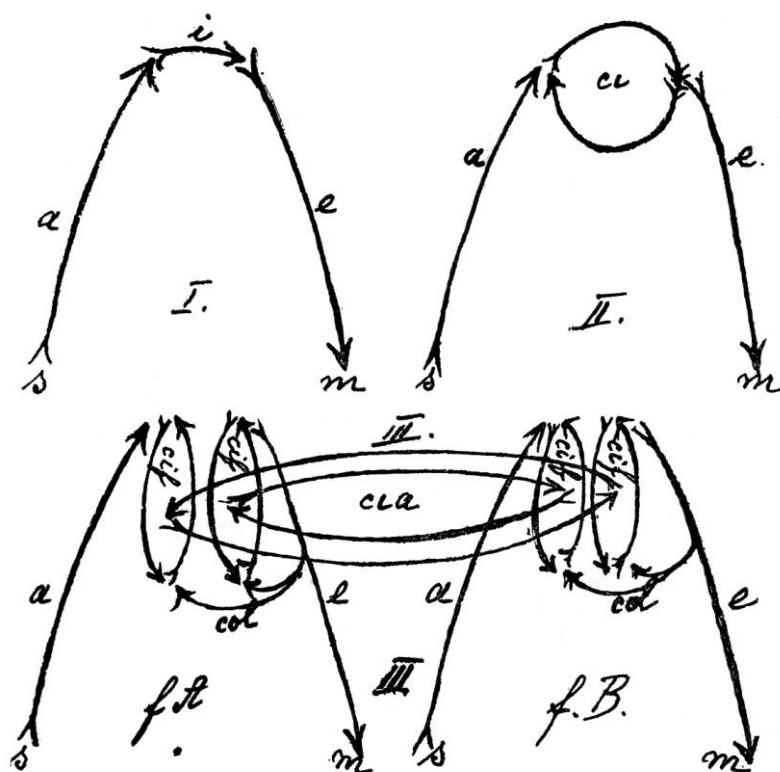


Figure 9. Diagrammatic scheme of *archikinesias* (I), *paleokinesias* (II) and *neokinesias* (III) according to Jakob [50 (p. 116)]. Abbreviations: a, s, sensory afferent system; e, m, motor efferent system; i, intercalated system; ci, intercalated microdynamism; fA, fB, cortical foci A and B; cif, focal intercalated microdynamism; cia, associative intercalated circuit; col, motor collateral.

The higher *neoneuronal* system subserves conscious acts, individuality and consciousness ('neokinesias') (Fig. 9, 11); it comprises two sectors, the limbic cortex ('introyente' or endogenous sphere) and the lateral cortex ('ambiente' or external

³ In his 1969 Hincks Memorial Lecture at Queen's University in Ontario, MacLean [49] begins his tripartite diatribe with 'Man's reptilian and limbic *inheritance*' (my italics).

environment). Time responses vary approximately from 20–30 msec for the ‘archikinesias’ and from 200–300 msec for the ‘neokinesias’ [53 (pp. 35–37)];⁴ in the latter instance, the major distance can be established through a central or volitional neokinetic transformation in a reaction time of 110–120 msec (the “fourth dimension of thought”).

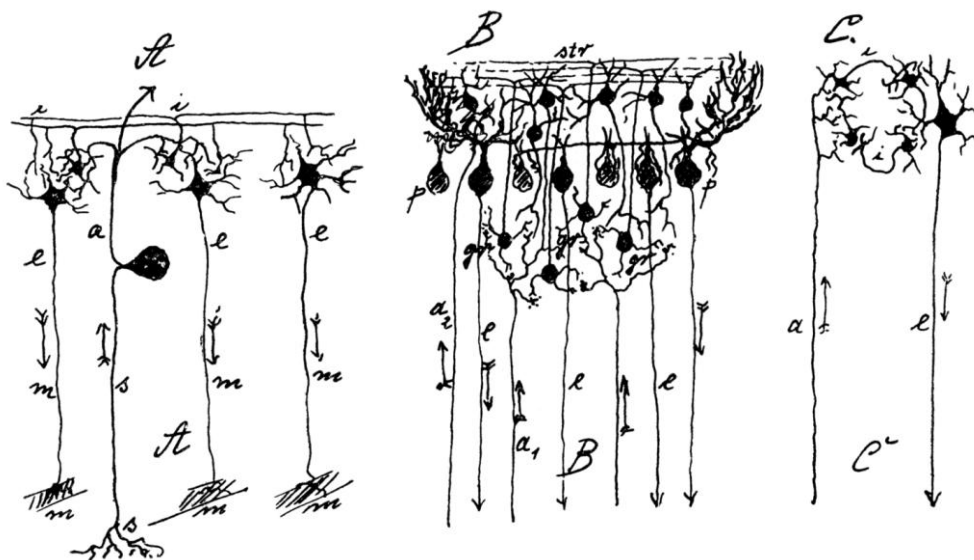


Figure 10. Histological organization of intercalated systems in (A) archikinesias, (B) cerebellar paleokinesias, and (C) striatal paleokinesias according to Jakob [50 (p. 119)]. Abbreviations: a, afferent; e, efferent; m, motor; s, sensory; a_1 , mossy fiber; a_2 , climbing fiber; P, Purkinje cells; gr, granule cells; str, stellate cells; i, intercalated element (interneuron).

Within the framework of the dynamic workings of the human cerebral cortex, the ‘neokinesias’ include (i) ‘gnosias’ (cognitive processes related to conscious orientation in one’s environment), (ii) ‘praxias’ (individual active intervention) and (iii) ‘symbolias’ (ideative abstraction to facilitate interindividual communication, such as the sociogenetic processes on which human culture is based) [47, 50, 53 (pp. 41–66), 60; cf. also 29, 61, 62 (pp. 297–303), 63–65]. Jakob [66 (p. 16)] later elaborated on these three concepts in his *Documenta Biofilosófica*, commenting that ‘gnosia’ (attentive orientation), ‘praxia’ (active or passive intervention) and ‘symbolia’ (communicative verbal formulation) represent three intimately linked sensory-motor phases that together form the true psychogenetic trinity (‘la verdadera trinidad psicocreadora’), from which “experience and thought are revealed as amalgamated neurodynamic realities.”

Jakob treated the theme of the phylogeny of the *archicortex*, *paleocortex* and *neocortex* in greater detail in the second part of his 1945 monograph on the yacaré [23 (pp. 99–109)].

⁴ These are remarkable calculations for having been written in the 1940s, if one considers that current views hold that consciousness arises from neurons in about 500 msec – the ‘neural time factor’ [54] – or less [55]; in other words, it takes a fraction of a second between the occurrence of a physiological stimulus in the parietal cortex and a subject becoming conscious of it [56], with the mind compensating for real time through a ‘backward referral’ experience [57]. On the efferent side, brain potentials fire a little over 300 msec before one has the conscious intention to act [58] and cerebral potentials may precede finger movement by up to 1 sec [59].

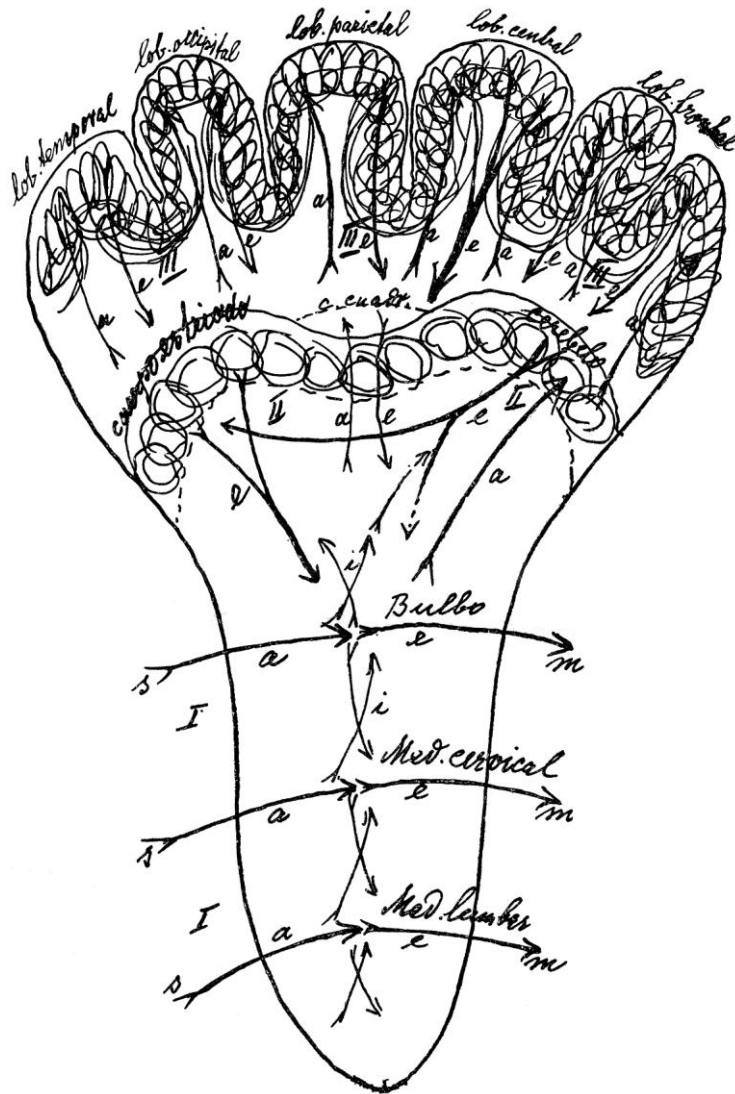


Figure. 11. Topographic depiction of the systems of archipsychism (I), paleopsychism (II) and neopsychism (III) according to Jakob [50 (p. 127)].

THE TRIPARTITE MENTAL APPARATUS OF PSYCHOANALYSIS

Freud formally introduced the full scope of his infamous three-fold model of the mental apparatus – comprising the id ('das Es'), the ego ('das Ich'), and the super-ego or ego ideal ('das Über-Ich' oder 'Ich-Ideal') – in his 1923 book *Das Ich und das Es* [67], which was translated into English as *The Ego and the Id* [68]. Freud revisited and supplemented the theme a decade later (1933) in his *New Introductory Lectures* [69].

Jacobson [70] argues that Freud's contributions to the neuron doctrine may have been overestimated as part of "the blatant hero worship," which led to a reverberation of psychoanalytic thought in the new field of neuroscience. The theory of MacLean [71] on the

processing of emotions by a network of deep brain structures seems to have found a general acceptance in the 1950s because of its conceptual correspondence to psychoanalytic theory [72]. As a matter of fact, MacLean [71] makes the point that “considered in the light of Freudian psychology, the visceral brain would have many of the attributes of the unconscious id.” Regarding the assumed phylogenetic components of the ‘triune brain,’ MacLean [49, 73] does mention a correspondence to Freud’s id, ego, and super-ego [74].

Sagan [3 (p. 79)] describes MacLean’s triune brain model as being only in weak accord with the tripartite mind of psychoanalytic theory and stresses that, owing to the neuroanatomical connections between its three component parts, the triune brain must be useful, just like the metaphor for the human psyche found in Plato’s *Phaedrus*. In that dialogue, Socrates likens the human soul to a chariot drawn by two horses, a black and a white, pulling in different directions and weakly controlled by the charioteer. Freud also described the *ego* as the rider of an unruly horse. Sagan [3] argues that an even better metaphor could be Freud’s division of the mind into *conscious*, *preconscious* and *unconscious*.⁵ A remarkable similarity can be seen between the metaphor of Plato’s chariot and MacLean’s neural substrates, the reptilian and paleomammalian brains corresponding to the two horses, and the neomammalian brain to the charioteer.

Freud’s and Jakob’s books, describing their respective landmark models of the tripartite mind and the tripsychic brain, were both published in the year 1923. Both investigators attribute a special emphasis to the body’s projection pattern on the cerebral cortex: having a sound background and an early successful career in neuroanatomy, Freud [68] describes the ego as being “first and foremost a bodily ego, not merely a surface entity, but itself the projection of a surface.”

According to Freud, a neurological analogy for the ego is its identification with the “cortical homunculus of the anatomists.” In a footnote first appearing in the authorized English translation of 1927 (absent from the German edition), this is further explained as the ego being “ultimately derived from bodily sensations, chiefly those springing from the surface of the body;” thus, it can be regarded as “a mental projection of the surface of the body, besides representing the superficies of the mental apparatus.”

In his atlases of comparative and human neuroanatomy, Jakob [20–22] stresses in more detail the topographic dissociation of the body’s projection pathways onto the lateral and medial surfaces of the cerebral hemispheres, depending on the perception of exogenous or endogenous signals, and introduces his pioneering concepts of the formation of sectors and pre-gyri, as well as the concept of a visceral brain with an anatomical correlate in the cingulate gyrus (reviewed in [31]).

THE TRIUNE BRAIN CONCEPT OF MACLEAN

Paul MacLean’s conception of a ‘triune’ pattern and organization of the human brain includes three fundamental brain types or subsystems – each with its own subjectivity, intelligence, spacetime sense, memory, motor and other functions – intermeshing as one.

⁵ In his paper on the phylogeny of the kinesias, Jakob [50] mentions a correspondence of plasmopsychic through archipsychic functions with the unconscious, of paleopsychic functions with the preconscious (which

Going phylogenetically and hierarchically from older to newer, over the past 200 million years, these are [49, 73, 75–78]:

- (1) The *reptilian* brain at the base, the most ancient heritage, first evolved in primeval reptiles and the great lizards, forms the matrix of the upper brainstem and comprises most of the reticular formation, the midbrain, the hypothalamus, the basal ganglia (archipallium), and the cerebellum; it mediates biological and endocrine equilibrium, via stereotypic behaviors and vital functions, such as survival and self-preservation, sleep-wakefulness regulation, drinking and feeding, mating, territorial possession, imitation, aggression, flight and ritualized combat, and the establishment of social hierarchies. It assures an immediate response in the present and it is privileged concerning olfaction.
- (2) The *paleomammalian* brain, the intermediate type that is distinguished by the presence of a primitive cortex, the limbic cortex; the limbic system is central in mediating feelings, emotions and affect – which necessitates a long-term memory and the motivation associated with it –, play, the sense of reality of oneself and the environment, the conviction of what is true or important, the recognition of offspring and parental care. It makes its appearance in the early mammals and it is based on the importance of vocalization and audition.
- (3) The *neomammalian* brain, which ‘mushroomed’ late in evolution and is characterized by the more highly differentiated form of the neocortex (neopallium); it forms the basis of interpersonal communication via spoken and written language, arithmetic, rationality, creative abilities, and the intellect. Typical of humans, the neomammalian brain with its evolved frontal lobes, subserves (rather than ‘understands’, cf. [79]) reason and symbolic language; it is ‘privileged’ with regards to vision, abstraction, association, imagination and future anticipation.

According to the triune brain theory, the integrated human brain is a synthesis of the three successively evolved ‘component’ brains, which, while operating as a whole, retain their original attributes and functions. Limbic regions (e.g. anterior cingulate, medial frontal and insular), phylogenetically conserved to a higher degree than the neocortical regions which mediate cognitive capacities, are associated with emotional responses and their intrinsic affective attributes [73, 80]. The types of mental function for which the reptilian, limbic and neomammalian brain are responsible, are respectively assigned by MacLean [73] as ‘protomentation’, ‘emotional mentation’ and ‘rational mentation’. In the relatively rapid human evolution, the three brain subsystems are imperfectly integrated, influencing individual and social behaviors that are under the commands of each individual or collective act.

MacLean chose the term ‘triune’ for his evolutionary brain theory because of the literal meaning of the word (three-in-one); the fact that his father was a Presbyterian minister may have something to do with such a choice, although MacLean reportedly regretted it [81], due to the potential confounding with the Christian doctrine.

genetically precedes conscious phenomena, and thus is differentiated from the subconscious, which he considers part of the conscious), and of neopsychic functions with the conscious (Fig. 10).

FURTHER TRIPARTITE MODELS OF THE HUMAN MIND

In a temporal confluence, Knopp [82], studying patients with Gilles de la Tourette disease and acute schizophrenia, proposed – in the same year as MacLean [75] formally introduced the triune brain concept – a tripartite brain concept as well, whereby a balanced and continuous reconciliation among three components or at least two levels of central integration constitutes the ‘rational brain’. According to Knopp’s proposition, the limbic lobe, the hypothalamic network and the autonomic nervous system neurophysiologically subserve *visceral experience*, the nigrostriatal system and the limbic lobe (*conscious*) *emotional experience*, and the neocortex *social experience* (*effectuation*).

In considering tripartite models of the mind, the synthetic neurophilosophical construct of Popper and Eccles [83] comes to mind, accounting for brain-mind interaction by means of their World 1 (liaison brain), World 2 (outer and inner sense and the self), and World 3 (cultural heritage).

In the cybernetic view, the nervous system operates as a tripartite system that involves *input* (sensory receptor), *integrating*, and *output* (muscle contraction) components [84]; this is based on a 19th century notion of anatomists and physiologists, and an ubiquitous principle of physiological psychology in the 20th century, of grouping brain structure and function into *sensory*, *association*, and *motor* systems [85]. Such properties accrete from the most fundamental properties of the nerve cell as a *receiving*, *conducting*, and *transmitting* functional unit, and the principle of dynamic polarization of neurons [86], which is at the core of neurobiology.

The triarchic model of the human mind propounded by Sternberg [87, 88] consists in *analytical*, *practical*, and *creative* sides of intelligence. Tigner and Tigner [89] argue that such a model may reflect the triptych developed by Aristotle of Stageira in his *Nicomachean Ethics* (350 B.C.). The Greek philosopher proposed a system of human intelligence comprising three virtues: ‘theoretical’ (διανόησις), ‘practical’ (φρόνησις), and ‘productive’ (ποίησις). The parallel conclusions of temporally disjoined inquiries by investigators working under disparate historical circumstances does not seem to be unusual in the historical evolution of psychological thought [89].

At the level of mind organization, Fodor [90] proposed a tripartite division of cognitive mechanisms, involving physical energy→symbol *transducers*, which record stimuli from the outside world and convert them into neural code, specialized modular *input systems*, which process raw data derived from the transducers, and a central *processor*, the site of higher cognitive processes that receives the outcome of input systems [91].

An established philosophical taxonomy, providing a tripartite structure of consciousness, divides it into *phenomenal*, *reflective*, and *access* consciousness [92, 93]. Phenomenal consciousness subserves the subjective feeling of mental content [94]; reflective consciousness is defined as the direct availability of the process of mental activities for access that allows one to access the steps of the reasoning process, whereas access consciousness is the direct availability of mental content that allows one to access the outcome of a reasoning process [93].

DISCUSSION

Based on the ideas exposed above, it becomes apparent that tripartite models abound in the attempt to shed light into the workings of the human brain and mind; they span over a spectrum from the philosophical to the biological. To attempt to draw parallels or pinpoint differences among various components in such a pleiad of systems forms a daunting task. Nonetheless, in considering the particular models in the evolutionary domain, Jakob's proposition of three hierarchically appearing 'psychisms' in the nervous system [47] seems to anticipate, by several decades, the 'triune brain' concept of MacLean [49, 75].

During his upbringing in Germany, Jakob acquired a strong background in philosophy [15] and throughout his career, Jakob [66, 95] maintained a philosophical perspective on biology in general and on neurobiology in particular (Figure 12); he realized some of the earliest interpretations of the limbic or 'internal' brain as a viscerio-emotional mechanism and the bidirectional communication between the internal organs and the splenial cortex, and the external environment and the lateral cortex [21, 22]. Although Jakob kept a distance from peripatetic metaphysics, he nevertheless adopted, in strictly biological terms, the Aristotelian notion of the psychic character (or 'psychism'): "That neurobiophylactic [neural life-protecting] complex of neuroenergetic reception, assimilation and reaction, which regulates the organism's vital necessities against variable factors in the external and inner environment, I call *psychism*" [96 (p. 8)]. In Jakob's synthesis, one can trace the influence of the precepts of his mentor von Strümpell, as well as of Italian positivism, particularly the views of philosopher Giovanni Marchesini (1868–1931) [30 (pp. 115–116)].

MacLean, on the other hand, planned to study philosophy before ending up studying medicine; he eventually proposed the creation of a new branch of knowledge ("epistemics") to look at things "from the inside out", combining neuroscience and psychology in an attempt to explain the subjective self and its relationship to the external and internal environment [97].

Jakob [47] attributed a life-preserving role ('biophylaxis') to phylopsychism – at the species – and ontopsychism – at the individual – level. MacLean highlighted the importance of the reptilian complex for integrating behaviors involved in self-preservation and in the preservation of the species [97].

Jakob [60] named 'praxias' the active individual intervention processes within the framework of the dynamic workings of the cerebral cortex, and treated 'tropism' within the spectrum of fundamental neurodynamic functions [47]; he further presented his ideas on life and mental experience relative to time at the basal, phylogenetic and ontogenetic levels in a paper under the encompassing title 'From tropism to the general theory of relativity' [98]. MacLean coined terms such as 'isopraxic' – to denote behaviors in which multiple members of a group perform the same thing – and 'tropistic' – to connote a behavior responding to partial representations of things, such as the marking on a prey [97].

In the 1990s, MacLean [99] placed special emphasis on the three cortical types that evolved in the forebrain of mammals, from mammalian-like reptiles (therapsids) through humans, to describe the idea of how resonance may contribute to the dynamic excitability of neural circuits by representing possible algorithms in the nervous system at the macroscopic, microscopic, molecular, and atomic level that underscore mental states and solutions for immediate or eventual actions.

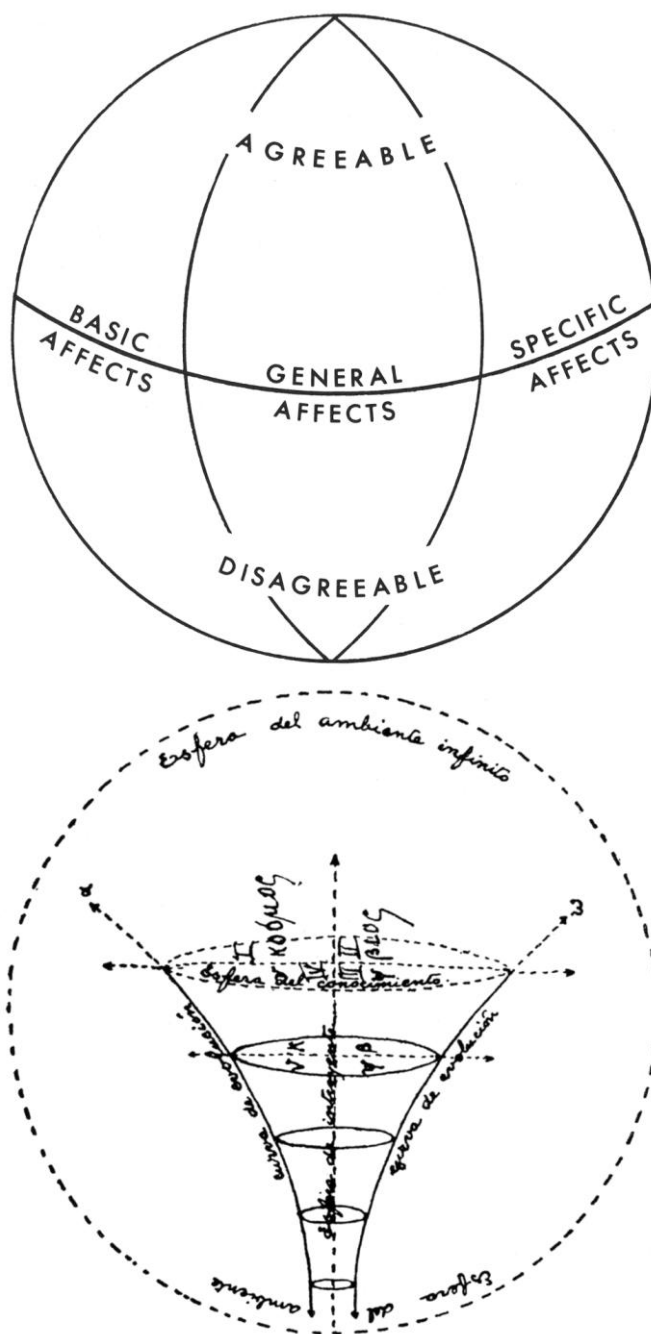


Figure 12. Upper: MacLean's [75 (p. 338)] scheme for viewing the world of affects, subjectively qualified into either agreeable or disagreeable. MacLean maintains that affects cannot be neutral, because "emotionally speaking, it is impossible to feel unemotional." He further subdivides affects into basic (informative about basic bodily needs), general (pertinent to situations, individuals or groups and the preservation of self or the species) and specific (occurring with activation of specific sensory systems). Lower: Jakob's [95] scheme of the empirical sphere with the four quadrants of the sciences: I. Cosmos (κόσμος), II. Life (βίος), III. Psyche (ψυχή) and IV. Order (νόμος). The sphere of the infinite environment is invaded by that of progressive knowledge, delimited by the curve of evolution.

He suggested that the forebrain is particularly important as a ‘central processor’ for mental experience, including sensation, perception, drive, affect, thought, and the precise facts of science, and concluded that a refined picture of the structure and chemistry of the brain’s circuitry accounting is needed, especially because of the central question of whether one may ever rely on the brain with its viscoelastic properties to reliably measure time and space and the general nature of things [99].

Over six decades earlier, in his classical exposé on the phylogeny of the kinesias, Jakob [50] employed the time spread of ‘corollary discharge’ – a mechanism proposed by Helmholtz, allowing a receiving system to either take into account or ignore self-generated sensory input during the monitoring of self-generated movements – in attempting to substitute *semovience* (the mind’s capacity to generate new causal actions through experienced inner life). Jakob explained such a substitution with the mediation of axon collaterals, which upload neural activity into focal intercalated microcircuits, and an acquired ‘associative system’ [30 (pp. 121, 144)].

The ideas and propositions independently formulated by Jakob and by MacLean, despite their time distance and different environments, reflect a substantial convergence in their reasoning. Thus, studies attempting to penetrate human behavior by means of evolutionary hints, might benefit by taking a closer look at Jakob’s contributions, which have largely remained unheeded in the English scientific literature and which contain information potentially pertinent to current problems in psychobiology.

CONCLUDING REMARKS

Born an ocean and five decades apart, Christofredo Jakob and Paul MacLean left their marks of productivity as interdisciplinary neuropsychiatrists, with special emphasis on comparative neurobiology and brain evolution. It is worth noting that the two investigators also died half a century apart, and published their tripartite models in 1923 and in 1970, respectively, when they both were 57 years of age. The fact that they never met, but formulated convergent propositions, can only lead one to recall the motto, “great minds think alike.”

The extent to which the two neuroevolutionary constructs are empirically supported remains a controversial issue even today. Considering the recurring triune theories on the underpinnings of the mind, witnessed over twenty-five centuries of human inquiry, one may ponder over a putative tendency of the human brain itself to construct or understand tripartite models of reality. Perhaps the hypothesis of an evolutionary trend to develop tripartite models of existence could some day be put to rigorous experimental testing.

REFERENCES

- [1] DeMyer, W. (1988). *Neuroanatomy*. Baltimore–Malvern: Williams & Wilkins/Harwal Publishing Co., p. 315.
- [2] Koestler, A. (1967). *The Ghost in the Machine*. London: Hutchinson & Co. Ltd., pp. 267–296.

- [3] Sagan, C. (1977). *The Dragons of Eden: Speculations on the Evolution of Human Intelligence*. New York: Random House, pp. 49–79.
- [4] Thérien, G., Verrier, H., & Beaudet, M. (1984). *Les Trois Cerveaux*. Montréal: Office National du Film du Canada.
- [5] Cory, G. A. Jr. (2003). MacLean's evolutionary neuroscience and the conflict systems neurobehavioral model: some clinical and social policy implications. In A. Somit, & S. A. Peterson (Eds.), *Human Nature and Public Policy: An Evolutionary Approach*. New York–Hampshire: Palgrave Macmillan, pp. 161–180.
- [6] Elliot Smith, G. (1901). The natural subdivision of the cerebral hemisphere. *Journal of Anatomy and Physiology (London)*, 35, 431–454.
- [7] Elliot Smith, G. (1927). *The Evolution of Man: Essays*, 2nd edn. London: Humphrey Milford–Oxford University Press.
- [8] Ariëns Kappers, C. U. (1909). The phylogenesis of the paleocortex and archicortex compared with the evolution of the visual neocortex. *Archives of Neurology and Psychiatry (London)*, 4, 161–173.
- [9] Jakob, C. (1941). *El Cerebro Humano: Su Ontogenia y Filogenia* (Folia Neurobiológica Argentina, Atlas III). Buenos Aires: Aniceto López.
- [10] Swanson, L. W. (2000). What is the brain? *Trends in Neurosciences*, 23, 519–527.
- [11] Edinger, L. (1909). Die Beziehungen der vergleichenden Anatomie zur vergleichenden Psychologie, Neue Aufgaben. In L. Edinger, & E. Claparède (Eds.), *Über Tierpsychologie: Zwei Vorträge* (aus dem Bericht über den III. Kongreß für Experimentelle Psychologie, 1908). Leipzig: J. A. Barth, pp. 1–30.
- [12] Striedter, G. F. (2005). *Principles of Brain Evolution*. Sunderland, MA: Sinauer Associates, Inc.
- [13] Tilney, F. (1927). The chief intracerebellar and precerebellar nuclei, with a demonstration with models and charts. *Brain*, 50, 275–276.
- [14] Tilney, F. (1927). The brain stem of tarsius. A critical comparison with other primates. *Journal of Comparative Neurology*, 43, 371–432.
- [15] Orlando, J. C. (1966). *Christofredo Jakob: Su Vida y Obra*. Buenos Aires: Editorial Mundi. http://electroneubio.secyt.gov.ar/Vida_y_obra_de_Christofredo_Jakob.htm
- [16] Triarhou, L. C., & del Cerro, M. (2006). Semicentennial tribute to the ingenious neurobiologist Christfried Jakob (1866–1956). 1. Works from Germany and the first Argentina period, 1891–1913. *European Neurology*, 56, 176–188.
- [17] Triarhou, L. C., & del Cerro, M. (2006). Semicentennial tribute to the ingenious neurobiologist Christfried Jakob (1866–1956). 2. Publications from the second Argentina period, 1913–1949. *European Neurology*, 56, 189–198.
- [18] Jacob, C. (1898). *A Klinikai Vizsgálási Módszerek Atlasza a Belgyógyászati Diagnostica és a Különös Kór- és Gyógytan Alapvonaláival* (fordította Ritoók Zsigmond). Budapest: Singer és Wolfner Kiadása.
- [19] Jakob, C. (1899). *Atlante del Sistema Nervoso nello Stato Sano e nel Patologico con un Sunto di Anatomia Patologica e Terapia del Medesimo*. Milano: Società Editrice Libreria.
- [20] Jakob, C. (1911). *Das Menschenhirn: Eine Studie über den Aufbau und die Bedeutung seiner Grauen Kerne und Rinde*. München: J. F. Lehmann.
- [21] Jakob, C., & Onelli, C. (1911). *Vom Tierhirn zum Menschenhirn: Vergleichend Morphologische, Histologische und Biologische Studien zur Entwicklung der*

- Grosshirnhemisphären und ihrer Rinde. I. Teil. Tafelwerk nebst Einführung in die Geschichte der Hirnrinde.* München: J. F. Lehmann.
- [22] Jakob, C., & Onelli, C. (1913). *Atlas del Cerebro de los Mamíferos de la República Argentina. Estudios Anatómicos, Histológicos y Biológicos Comparados sobre la Evolución de los Hemisferios y de la Corteza Cerebral.* Buenos Aires: Imprenta de Guillermo Kraft.
- [23] Jakob, C. (1945). *El Yacaré (Caiman latirostris) y el Origen del Neocortex: Estudios Neurobiológicos y Folkloricos del Reptil más Grande de la Argentina* (Folia Neurobiológica Argentina, Tomo IV). Buenos Aires: Aniceto López.
- [24] Jakob, C. (1943). *El Pichiciego (Chlamydomorphus Truncatus): Estudios Neurobiológicos de un Mamífero Misterioso de la Argentina* (Folia Neurobiológica Argentina, Tomo II). Buenos Aires: Instituto de Biología de la Facultad de Filosofía y Letras.
- [25] Barraquer-Bordas, L. (1954). *Fisiología y Clínica del Sistema Límbico: Aportaciones Recientes al Conocimiento de las Bases Neurofisiológicas de la Personalidad.* Madrid: Paz Montalvo, pp. 136–137.
- [26] Barraquer-Bordas, L. (1976). *Neurología Fundamental: Fisiopatología, Semiología, Síndromes, Exploración*, 3rd edn. Barcelona: Toray, p. 596.
- [27] Orlando, J. C. (1964). Sobre el cerebro visceral. Documentación histórica de una prioridad científica. *Revista Argentina de Neurología y Psiquiatría*, 1, 197–201.
- [28] Goldar, J. C. (1975). *Cerebro Límbico y Psiquiatría.* Buenos Aires: Salerno.
- [29] Faccio, E. J. (1991). Christofredo Jakob y el origen del psiquismo. *Alcmeón – Revista Argentina de Clínica Neuropsiquiátrica*, 3, 331–348.
- [30] Szirko, M. (1995). A la antropología ganglionar desde la kinesiología: un fallido ensayo de extrapolar lo orgánico (Noticia preliminar). *Electroneurobiología (Buenos Aires)*, 2, 104–169.
- [31] Triarhou, L. C. (2008). Centenary of Christfried Jakob's discovery of the visceral brain: An unheeded precedence in affective neuroscience. *Neuroscience and Biobehavioral Reviews*, 32, 984–1000.
- [32] MacLean, P. D. (1969). The hypothalamus and emotional behaviour. In W. Haymaker, E. Anderson, & W. J. H. Nauta (Eds.), *The Hypothalamus*. Springfield, IL: Charles C Thomas, pp. 659–678.
- [33] Marino, R. Jr. (1975). *Fisiologia das Emoções: Introdução à Neurologia do Comportamento, Anatomia e Funções do Sistema Limbico.* São Paulo, Brasil: Sarvier S.A. Editora do Livros Médicos.
- [34] MacLean, P. D. (1985). Evolutionary psychiatry and the triune brain. *Psychological Medicine*, 15, 219–221.
- [35] Lautin, A. (2001). *The Limbic Brain.* New York: Kluwer Academic–Plenum Publishers, pp. 69–98.
- [36] Ploog, D. (2003). The place of the triune brain in psychiatry. *Physiology and Behavior*, 79, 487–493.
- [37] Perna, G. (2005). *Las Emociones de la Mente: Biología del Cerebro Emotivo.* Madrid: Tutor.
- [38] Reep, R. L., Finlay, B. L., & Darlington, R. B. (2007). The limbic system in mammalian brain evolution. *Brain Behavior and Evolution*, 70, 57–70.

-
- [39] Beare, J. I. (1906). *Greek Theories of Elementary Cognition from Alcmaeon to Aristotle*. Oxford: Clarendon Press.
 - [40] Stocks, J. L. (1915). Plato and the tripartite soul. *Mind – A Quarterly Review of Philosophy*, 24, 207–221.
 - [41] Georgulis, K. D. (1957). Plato. *Helios Encyclopaedical Lexikon (Athens)*, 16, 7–81.
 - [42] Burnet, J. (1920). *Early Greek Philosophy*, 3rd edn. London: A. & C. Black, Ltd..
 - [43] Doty, R. W. (2007). Alkmaion's discovery that brain creates mind: A revolution in human knowledge comparable to that of Copernicus and of Darwin. *Neuroscience*, 147, 561–568.
 - [44] Cohen, E. D. (1988). *The Mind of the Bible-Believer*. Amherst, NY: Prometheus Books, p. 121.
 - [45] Pinker, S. (2002). *The Blank Slate: The Modern Denial of Human Nature*. London: Allen Lane, p. 85.
 - [46] Edgeworth, R. J. (1994). The tripartite soul in Plato, Dostoyevsky, and Aldiss. *Neophilologus*, 78, 343–350.
 - [47] Jakob, C. (1923). *Elementos de Neurobiología, volumen I: Parte Teórica* (Biblioteca Humanidades, Tomo III). La Plata, Argentina: Facultad de Humanidades y Ciencias de la Educación de la Universidad Nacional de La Plata.
 - [48] Jakob, C. (1914). La psicología orgánica y su relación con la biología cortical (Referat von R. Allers). *Zeitschrift für die Gesamte Neurologie und Psychiatrie*, 9, 804–805.
 - [49] MacLean, P. D. (1973). *A Triune Concept of the Brain and Behaviour* (The Clarence Hincks Memorial Lectures, Volume 2, edited by T. J. Boag and D. Campbell). Toronto–Buffalo: Ontario Mental Health Foundation–University of Toronto Press, pp. 1–66.
 - [50] Jakob, C. (1935). La filogenia de las kinesias: Sobre su organización y dinamismo evolutivo. *Anales del Instituto de Psicología de la Facultad de Filosofía y Letras de la Universidad de Buenos Aires*, 1, 109–127.
 - [51] Jakob, C. (1940). *Ontogenia del Sistema Nervioso Humano*. La Plata–Buenos Aires: Universidad Nacional de La Plata, Facultad de Humanidades y Ciencias de la Educación–Imprenta López.
 - [52] Jakob, C. (1936). *La Organización Subcortical del Sistema Nervioso Central de los Vertebrados Superiores: El Paleoencéfalo y sus Funciones Instintivas*. La Plata–Buenos Aires: Facultad de Humanidades y Ciencias de la Educación, Universidad Nacional de La Plata–Imprenta y Casa Editora «Coni».
 - [53] Jakob, C. (1941). *Neurobiología General* (Folia Neurobiológica Argentina, Tomo I). Buenos Aires: Aniceto López.
 - [54] Libet, B. (1999). How does conscious experience arise? The neural time factor. *Brain Research Bulletin*, 50, 339–340.
 - [55] Gazzaniga, M. (1998). *The Mind's Past*. Berkeley–London: University of California Press, pp. 69–82.
 - [56] Libet, B., Alberts, W. W., Wright, E. W. Jr., Delattre, L., Levin, G., & Feinstein, B. (1964). Production of threshold levels of conscious sensation by electrical stimulation of human somatosensory cortex. *Journal of Neurophysiology*, 27, 546–578.
 - [57] Libet, B., Wright, E. W. Jr., Feinstein, B., & Pearl, D. K. (1979). Subjective referral of the timing for a conscious sensory experience: a functional role for the somatosensory specific projection system in man. *Brain*, 102, 193–224.

-
- [58] Libet, B., Gleason, C. A., Wright, E. W. Jr., & Pearl, D. K. (1983). Time of conscious intention to act in relation to onset of cerebral activities (readiness potential): the unconscious initiation of a freely voluntary act. *Brain*, 106, 623–642.
 - [59] Kristeva, R., Keller, E., Deecke, L., & Kornhuber, H. H. (1979). Cerebral potentials preceding unilateral and simultaneous bilateral finger movements. *Electroencephalography and Clinical Neurophysiology*, 47, 229–238.
 - [60] Jakob, C. (1921). La teoría actual de las gnosias y praxias como factores fundamentales en el dinamismo de la corteza cerebral. *Crónica Médica (Lima)*, 38, 17–24.
 - [61] Szirko, M. (1991). Definición de psiquismo y de conocimiento sensible, retención de las memorias, evolución del sistema nervioso, y relaciones mente-cuerpo o nexo psicofísico, en la Escuela Neurobiológica Argentino-Germana. *Electroneurobiología (Buenos Aires)*, 1 [Supl. 2], I–XIV.
 - [62] Kurowski, M. (2001). *La Obra Psicológica de Juan Cuatrecasas Arumí (1899–1990)*. Madrid: Universidad Complutense, Facultad de Psicología.
 - [63] Crocco, M. (2004). ¡Alma e’ reptil! Los contenidos mentales de los reptiles y su procedencia filética. *Electroneurobiología (Buenos Aires)*, 12, 1–72.
 - [64] Capizzano, A. A. (2006). Actualidad del pensamiento de Cristofredo Jakob. *Revista del Hospital Italiano de Buenos Aires*, 26, 71–73.
 - [65] Crocco, M. (2007). Christofredo Jakob. In *Wikipedia, la Enciclopedia Libre*. http://es.wikipedia.org/wiki/Christofredo_Jakob
 - [66] Jakob, C. (1946). *Documenta Biofilosófica. Folleto I. Biología y Filosofía. A: Aspectos de sus divergencias y concomitancias. B: Ensayo de Psicogenia orgánica* (Folia Neurobiológica Argentina, Tomo V). Buenos Aires: López y Etchegoyen.
 - [67] Freud, S. (1978). Das Ich und das Es [1923]. In A. Freud, & I. Grubrich-Simitis (Eds.), *Sigmund Freud Werkausgabe in zwei Bänden, Band 1: Elemente der Psychoanalyse*, 2. Aufl. Frankfurt a.M.: S. Fischer Verlag GmbH, pp. 369–401.
 - [68] Freud, S. (1974). *The Ego and the Id* [1923] (transl. by J. Riviere, ed. by J. Strachey). London: The Hogarth Press and the Institute of Psycho-Analysis, pp. 9–17.
 - [69] Freud, S. (1978). Neue Folge der Vorlesungen zur Einführung in die Psychoanalyse [1933]. In A. Freud, & I. Grubrich-Simitis (Eds.), *Sigmund Freud Werkausgabe in zwei Bänden, Band 1: Elemente der Psychoanalyse*, 2. Aufl. Frankfurt a.M.: S. Fischer Verlag GmbH, pp. 402–418.
 - [70] Jacobson, M. (1993). *Foundations of Neuroscience*. New York–London: Plenum Press, pp. 204–205.
 - [71] MacLean, P. D. (1949). Psychosomatic disease and the “visceral brain”: Recent developments bearing on the Papez theory of emotion. *Psychosomatic Medicine*, 11, 338–353.
 - [72] Kolb, B., & Whishaw, I. Q. (1996). *Fundamentals of Human Neuropsychology*, 4th edn. New York: W. H. Freeman and Co., pp. 417–420.
 - [73] MacLean, P. D. (1990). *The Triune Brain in Evolution: Role in Paleocerebral Functions*. New York–London: Plenum Press.
 - [74] Peper, M., & Markowitsch, H. J. (2001). Pioneers of affective neuroscience and early concepts of the emotional brain. *Journal of the History of the Neurosciences*, 10, 58–66.
 - [75] MacLean, P. D. (1970). The triune brain, emotion, and scientific bias. In F. O. Schmitt (Ed.), *The Neurosciences: Second Study Program*. New York: Rockefeller University Press, pp. 336–349.

-
- [76] MacLean, P. D. (1977). The triune brain in conflict. *Psychotherapy and Psychosomatics*, 28, 207–220.
 - [77] MacLean, P. D. (1990). *Les Trois Cerveaux de l'Homme: Textes Traduits de l'Américain, Notes et Commentaires de Roland Guyot* (Collection «La Fontaine des Sciences» dirigé par Gérard Klein). Paris: Éditions Robert Laffont, S.A..
 - [78] Schoffeniels, E., Schmerling, P., & MacLean, P. D. (1994). Journée Commemorative du Bicentenaire de Pierre Schmerling: Colloque: Théorie des trois cerveaux de Paul Donald MacLean et incidences en Psychiatrie: vendredi 15 novembre 1991, Hôpital Psychiatrique du Petit Bourgogne, Liège (*Acta Psychiatrica Belgica*, 94, fasc. 4–6). Bruxelles, Société de Médecine Mentale.
 - [79] Bennett, M. R., & Hacker, P. M. S. (2001). Perception and memory in neuroscience: a conceptual analysis. *Progress in Neurobiology*, 65, 499–543.
 - [80] Panksepp, J. (2002). The MacLean legacy and some modern trends in emotion research. In G. A. Cory, Jr., & R. Gardner, Jr. (Eds.), *The Evolutionary Neuroethology of Paul MacLean*. Westport, CT: Praeger, pp. ix–xxvii.
 - [81] Lambert, K. G. (2003). The life and career of Paul MacLean: A journey toward neurobiological and social harmony. *Physiology and Behavior*, 79, 343–349.
 - [82] Knopp, W. (1970). Man's tripartite brain and psychosomatic medicine. *Psychotherapy and Psychosomatics*, 18, 130–136.
 - [83] Popper, K. R., & Eccles, J. C. (1977). *The Self and its Brain*. Berlin–Heidelberg: Springer International, pp. 358–365.
 - [84] Hubel, D. H. (1979). The brain. *Scientific American*, 241, 44–53.
 - [85] Uttal, W. R. (2001). *The New Phrenology: The Limits of Localizing Cognitive Processes in the Brain*. Cambridge, MA: MIT Press, p. 25.
 - [86] Ramón y Cajal, S. (1954). *Neuron Theory or Reticular Theory? Objective Evidence of the Anatomical Unity of Nerve Cells* (transl. by M. Ubeda Purkiss, C.A. Fox). Madrid: Consejo Superior de Investigaciones Científicas/S. Aguirre Torre.
 - [87] Sternberg, R. J. (1984). Toward a triarchic theory of human intelligence. *Behavioral and Brain Sciences*, 7, 269–315.
 - [88] Sternberg, R. J. (1988). *The Triarchic Mind: A New Theory of Human Intelligence*. New York–London: Viking Press.
 - [89] Tigner, R. B., & Tigner, S. S. (2000). Triarchic theories of intelligence: Aristotle and Sternberg. *History of Psychology*, 3, 168–176.
 - [90] Fodor, J. A. (1983). *The Modularity of Mind*. Cambridge, MA: MIT Press.
 - [91] Sterelny, K. (1990). *The Representational Theory of Mind*. Oxford: Basil Blackwell Ltd., p. 75.
 - [92] Block, N. (1995). On a confusion about a function of consciousness. *Behavioral and Brain Sciences*, 18, 227–287.
 - [93] Sun, R. (2002). *Duality of the Mind: A Bottom Up Approach Toward Cognition*. Mahwah, NJ: Lawrence Erlbaum Associates Inc., pp. 176–190.
 - [94] Nagel, T. (1974). What is it like to be a bat? *Philosophical Reviews*, 4, 435–450.
 - [95] Jakob, C. (1945). El cerebro humano: Su significación filosófica. Ensayo de un programa psico-bio-metafísico, después de 50 años de dedicación neurobiológica. *Revista Neurológica de Buenos Aires*, 10, 89–110.

-
- [96] Jakob, C. (1939). *El Neoencéfalo: Su Organización y Dinamismo*. La Plata–Buenos Aires: Universidad Nacional de La Plata, Facultad de Humanidades y Ciencias de la Educación–Imprenta López.
- [97] Holden, C. (1979). Paul MacLean and the triune brain. *Science*, 204, 1066–1068.
- [98] Jakob, C. (1922). Del tropismo a la teoría general de la relatividad: Un capítulo biopsicofiláctico. *Humanidades (La Plata)*, 3, 45–58.
- [99] MacLean, P. D. (1997). The brain and subjective experience: question of multilevel role of resonance. *Journal of Mind and Behavior*, 18, 247–268.
- [100] Ploog, D. (1970). Social communication among animals. In F. O. Schmitt (Ed.), *The Neurosciences: Second Study Program*. New York: Rockefeller University Press, pp. 349–361.

Chapter 17

CATEGORY-SPECIFIC SEMANTICS IN ALZHEIMER'S DEMENTIA AND NORMAL AGING?

***Keith R. Laws^{*1}, Tim M Gale^{1,2,3}, F. Javier Moreno-Martínez⁴,
Rebecca L. Adlington¹, Karen Irvine¹ and Sunil Sthanakiya¹***

¹School of Psychology, University of Hertfordshire, UK

²Department of Psychiatry, QEII Hospital, Welwyn Garden City, UK

³School of Computer Science, University of Hertfordshire, UK

⁴Departamento de Psicología Básica I, U.N.E.D. Madrid, Spain

ABSTRACT

Category-specific deficits represent the archetypal illustration of domain-specific cognitive processes. These deficits describe individuals who, following certain types of neurological damage show dissociations in their ability to recognise and name exemplars from within specific domains e.g. living or nonliving things. Cases described over the past 25 years have formed a pivotal foundation for the development of models describing the structure and organisation of lexical-semantic memory. In this chapter, we review the evidence on whether category deficits in AD are consistent with the loss of isolated categorical information, an artefact of confounding psycholinguistic variables (e.g. age of acquisition, word frequency, and familiarity) or an exaggeration of some pre-existing normal cognitive difference.

Finally, we present emerging evidence that female AD patients show worse semantic memory impairment than male patients. In this context, we discuss a possible role for the apolipoprotein E (APOE) ε4 allele, which is associated with a greater probability for developing AD in women and impacts more on the cognitive performance of healthy women than men.

Keywords: Alzheimer's disease. Category-specificity. APOE. Semantic memory. Healthy aging

^{*} University of Hertfordshire College LaneHatfield, Hertfordshire AL10 9AB, UK.

SEMANTIC MEMORY

How many legs does an octopus have? What is the capital of Peru? What is the meaning of the word 'Justice'? The answers to such questions reside within our semantic memory. Since the seminal work by Tulving (1972), one of the most important distinctions in human memory is arguably that between episodic and semantic memory. While episodic memory is autobiographical and varies between individuals thus reflecting their differing personal experience, semantic memory is more invariant across individuals and incorporates more culturally shared knowledge. Broadly speaking, semantic memory comprises a decontextualised knowledge base- 'an organized body of knowledge involving words, concepts, their meanings, their associations, and the rules for manipulating these symbols and concepts' (Nebes, 1989: p. 377). Although semantic and episodic memory are often discussed as isolable entities, their interaction should not be overlooked: while stored semantic knowledge must influence our comprehension of day-to-day experiences, the reverse is also undoubtedly true, with much evidence suggesting that semantic memory is constantly updated and modified by personal experience (McCarthy & Warrington, 1992; Snowden, Griffiths & Neary, 1994).

Semantic memory plays a crucial role in object recognition and naming: contemporary models of object recognition posit that information flows from perceptual to semantic and to phonological representations when naming a visually presented item (e.g. Humphreys, Riddoch & Quinlan, 1988). Disorders of semantic memory have been described in the neuropsychological literature following a variety of pathologies including traumatic head injury (Funnell & Sheridan, 1992), herpes simplex encephalitis (Laws & Sartori, 2005), semantic dementia (Snowden Goulden & Neary, 1989) and Alzheimer's disease (Chertkow & Bub, 1990).

Semantic Memory Impairment in Alzheimer's Disease

Current estimates are that someone in the USA will be diagnosed with Alzheimer's disease (AD) every 72 seconds (Alzheimer's Association, 2007). Given this high prevalence, Alzheimer's disease is one of the most extensively studied conditions in the context of semantic memory impairment and has a well-established association with a marked impairment in semantic memory (Bayles & Tomoeda, 1983; Bayles, Tomoeda, & Trosset, 1990; Chertkow & Bub, 1990; Done & Gale, 1997; Hodges, Salmon, & Butters, 1991; Martin & Fedio, 1983; Salmon, Butters, & Chan, 1999). Semantic dysfunction has been described across an extensive range of tasks including: picture naming (Silveri, Daniele, Giustolisi, & Gainotti, 1991); word to picture matching (Garrard, Lambon Ralph, Watson, Powis, Patterson, & Hodges, 2001); object decision (Daum, Riesch, Sartori & Birbaumer, 1996); semantic association (Mauri, Daum, Sartori, Riesch & Birbaumer, 1994); probe questioning (Done & Gale, 1997); and naming to definition (Mondini & Semenza, 2006).

Patients with AD have well-documented progressive word-finding difficulties. Indeed, AD patients tend to produce semantically-related naming errors (e.g. 'tiger' for leopard; 'celery' for asparagus); a strong item-to-item consistency across different tasks that tap semantic representations (Chertkow & Bub, 1990); and a strong relationship between naming

ability, attribute knowledge (Harley & Grant, 2004), and their ability to provide object descriptions (Lambon Ralph, Patterson & Hodges, 1997). Such findings strongly support the view that semantic disruption underpins the anomia in AD patients and, furthermore, it has been suggested that semantic memory impairment emerges early in the course of AD, being evident even in Mild Cognitive Impairment cases i.e. pre-AD neuropathology (Joubert, Felician, Barbeau, Didic, Poncet, Ceccaldi, 2008; Vogel, Gade, Stokholm, & Waldemar, 2005). Indeed, estimates concerning the incidence of semantic memory deficits in mild AD suggest it may be as high as 50% (Hodges, Salmon & Butters, 1992).

Category-Specific Semantic Impairments

One issue that has received increasing attention is whether the anomia seen in AD is category-specific i.e. do individuals with AD show a selective or differential loss of semantic knowledge for some categories over others? In the neuropsychological literature, category-specificity is most often discussed in terms of a functional or neuroanatomical distinction between knowledge of living and non-living things, with a relative sparing of the latter being the more frequently reported profile (for recent reviews see Capitani, Laiacina, Mahon, & Caramazza, 2003; Laws, 2005). Category-specific deficits represent the archetypal illustration of domain-specific cognitive processes. These deficits describe individuals who, following certain types of neurological damage, show differences in their ability to recognize and name exemplars from different categories or semantic domains: living (e.g. animals, fruits or vegetables) and nonliving (e.g. tools, vehicles or furniture). The search for category-deficits i.e. dissociations between selectively preserved and lost cognitive domains of function is central to the idea that the human mind has a modular structure (Fodor, 1983); and has been pivotal in the development of models that describe the structure, organization and deterioration of semantic memory, as well as in models of object recognition more generally.

Detailed descriptions of category specific cases have accumulated over the past 25 years, following the seminal report by Warrington and Shallice (1984) of four patients with herpes simplex encephalitis, each of whom demonstrated a selective impairment in their ability to name living relative to nonliving things. Finding such impairment in several patients with the same condition suggests that the cognitive profile is strongly associated with a specific neuro-anatomical substrate affected by brain pathology, rather than being a sporadic phenomenon arising from the random impact of neurological impairment (Gainotti, 2000). This non-randomness is reinforced by the fact that living and nonliving deficits do not occur in equal numbers (the ratio being approximately 5:1 for living: nonliving deficits reported, see Laws & Gale 2002). Indeed, the vast majority of single cases reported with living thing deficits have suffered lesions to the anterior temporal lobe (Gainotti, 2005) and this is perhaps exemplified by the association of temporal lobe pathology in herpes simplex encephalitis and the presence of category effects (e.g. Laws & Sartori, 2005). Moreover, a specific role has been proposed for the medial temporal structures (hippocampus and amygdala) in the greater biological significance of living than nonliving things for humans, while frontal regions may be more important for the latter category (Gainotti, 2005; Silveri et al, 1991). Temporal lobe pathology is an early and prominent pathological feature of AD (Braak & Braak, 1991; 1996) and the finding of semantic memory impairments early in the course of AD is consistent with the

pathological changes in the parahippocampal regions from early in the course of the disease (Braak & Braak, 1991).

Category-Specificity in AD

Despite the strong association between AD and semantic impairment, the presence of category-specific impairments in AD remains contentious: some studies report an impairment of living things (Montanes, Goldblum, & Boller, 1995; Silveri, et al., 1991), others have found no category effects (Hodges et al., 1992; Tippett, Grossman, & Farah, 1996) while still others report impairments of both living and nonliving things in the same sample of patients (Laws, Gale, Leeson, & Crawford, 2005; Moreno-Martínez, Tallón-Barranco, & Frank-García, 2007, Tippett, Meier, Blackwood, & Diaz-Asper, 2007) – see Tables 1 and 2.

Examining data from over 500 AD patients and 500 healthy controls in 21 studies, a recent meta-analysis reported that AD patients showed impaired naming for both living and nonliving things when compared to controls (Laws, Adlington, Gale, Moreno-Martinez, & Sartori, 2007). Although more studies documented living than nonliving thing deficits (13:8 respectively), no significant difference emerged in the effect sizes for naming living and nonliving things ($d=1.76$ and $d=1.49$ respectively). This is somewhat surprising given the emphasis on the number of studies reporting category effects for living things in this patient group. As noted by Laws and colleagues (Laws, 2005; Laws et al., 2007; Laws, Gale, Leeson & Crawford, 2005) the higher prevalence of living reports may partly reflect the tendency of some researchers to make within-group rather than between-group comparisons. In other words, some studies simply compare the absolute numbers of living and nonliving things named *within* the patient group (rather than with reference to a healthy control group). Although it may seem self-evident that patient performance be compared to that of controls, this is less common than one might imagine. Laws (2005) provided dramatic examples to show how absolute category advantages can even mislead about *the direction* of a deficit. Figure 1 displays one hypothetical pattern (described by Laws 2005 as a *paradoxical deficit*) in which absolute worse performance by patients in one category (in this example, for living things) reverses to a nonliving deficit when compared to the performance of healthy individuals.

Item Variables Affecting Category-Specificity: Confounding (Nuisance) Variables

Silveri et al (1991) conducted the first study to address the issue of category-specificity in a sample of AD patients. These authors compared 15 AD patients with 10 age- and education-matched controls on a confrontation-naming task using coloured images of 20 living and 20 nonliving things. Overall naming accuracy in the patients was impaired relative to the controls, but this pattern was especially marked for living things and sustained across mild and moderate cases of the disease.

Table 1. Studies documenting a category effect in AD patient

Study	Patient <i>n</i> (M-F)		Control <i>n</i> (M-F)	Patient Age	Control Age	Patient Education (years)	Control Education (years)	Patient MMSE	Control MMSE	Stimuli <i>n</i> (LT-NLT)	Confounds controlled
Silveri et al ¹⁹⁹¹	15		10	M	M	M	M	-	-	(20-20)C	Freq, Pro
Daum et al ¹⁹⁹⁶	8(2-6)		9(4-5)	66.4 ^M	67.1 ^M	-	-	13.1	30	(32-32)MC	Fam, VC, NF
Gonnerman et al ¹⁹⁹⁷	A	15	15	75.5 ^M	74.3 ^M	13.7 ^M	15.5 ^M	19	29	(12-24)MC	Pro
	B	15	14	76.3 ^M	74.1 ^M	13.7 ^M	15.5 ^M	18	29	(24-48)MC	Freq
Garrard et al ¹⁹⁹⁸	58(27-31)		46(12-34)	68	72.9	11.6	10.42	19.9	28.9	(24-24)MC	Pro, LF
Grossman et al ¹⁹⁹⁸	16		14	74.1 ^M	69.1 ^M	15.1 ^M	15.4 ^M	21.3	29.1	(36-36)CP	LF
Fung et al ²⁰⁰¹	18(7-11)		60(28-32)	80.6	76.6	11.2	12.5	22.5	-	(45-45)MC	NAC, LF, Fam, VC
Laws et al ²⁰⁰²	18(4-14)		26(14-12)	77.5	72.35	-	-	18.0	-	(60-60)C	Fam, NF
Zannino et al ²⁰⁰²	53(19-34)		30(19-11)	68.6 ^M	68.9 ^M	4.5 ^M	5.5 ^M	20.6	-	(30-30)MC	AoA, NF, Pro, Fam, Img, NA, VC
Laws et al ²⁰⁰³	18		26	77.5	72.39	-	-	-	-	Set 1(32-32)MC Set 2(60-60)C	Fam, NF
Laws et al ²⁰⁰⁵	A	9(2-7)	12(4-8)	81.1	77.9	-	-	13.7	-	Set 1(20-20)MC	(1,2)VC (1,2,3)Fam, NF
	B	18(4-14)	22(12-10)	77.4	71.54	-	-	18.0	-	Set 2(32-32)MC Set 3(60-60)C	
Laws & Sartori ²⁰⁰⁵	19(4-15)		15(6-9)	77.9 ^M	75.3 ^M	4.7 ^M	6.28 ^M	19.3	27.4	(32-32)MC	Freq, Fam, VC
Zannino et al ²⁰⁰⁶	20(8-12)		-	72.5	-	8.8	-	18.1	-	(32-32)MC	LF, AoA, Fam, VC
Albanese ²⁰⁰⁷	48(28-20)		40(20-20)	75.9	74.9	10	9.58	22.8	28.3	(77-78)MC	LF, Pro, Fam, AoA, NA, VC
Laws et al ²⁰⁰⁷	11(9-2)		22(10-12)	76.3	75.5	7.3	7.1	19.7	27.9	(32-32)MC	Fam, VC, NF
Zannino et al ²⁰⁰⁷	10(5-5)		10(4-6)	76.4 ^M	75.6 ^M	9.3 ^M	10 ^M	18.3	-	(32-32)MC (32-32)CP	LF, AoA, Fam, VC
Gale et al ^{in press}	28(9-19)		24(13-11)	83	78	-	-	22.1	-	(50-50)MC	LF, Fam, VC

Table 2. Studies reporting no category effect in AD patients

Study	Patient <i>n</i> (M-F)	Control <i>n</i> (M-F)	Patient Age	Control Age	Patient Education (years)	Control Education (years)	Patient MMSE	Control MMSE	Stimuli <i>n</i> (LT-NLT)	Confounds controlled
Hodges et al ¹⁹⁹²	22(13-9)	26(12-14)	69.5 ^M	72.3 ^M	13.7 ^M	14.6 ^M	20.7	29.6	(24-24)MC	Pro
Montanes et al 1995	25(5-20)	25(12-13)	75 ^M	70.6 ^M	6 ^M	8 ^M	21	-	Set 1(24-24)MC Set 2(22-22)C	(1)VC (2)LF
Gainotti et al 1996	16	11	68.3 ^M	69.4 ^M	6.3 ^M	9.3 ^M	12.8	-	(20-20) C	LF, VC, fam
Tippett et al ¹⁹⁹⁶	12(5-9)	-	75.9	-	15.5	-	17.76	-	Set 1(20-20)C Set 2(34-34)MC Set 3(12-12)MC	(1,2,3)Freq, Pro (3)VC
Laiacona et al 1998	26(11-15)	52(22-30)	70.2 ^M	^M	6.1 ^M	^M	-	-	(30-30)MC	LF, Fam, Pro, NA, IA, AoA, VC
Silveri et al ²⁰⁰²	39	12	70.2 ^M	71.3 ^M	9.2 ^M	9.2 ^M	17.9	-	(40-40)MC	AoA, LF, Pro, Fam, NA, WL
Perri et al ²⁰⁰³	21(6-15)	23(6-17)	70.7 ^M	68 ^M	9.2 ^M	10 ^M	21.2	-	(30-30)MC	LF, Pro, Fam, NA, IA, VC
Harley et al ²⁰⁰⁴	9(4-5)	6(1-5)	85	74	-	-	11	-	(20-20)MC	NA, Fam, VC
Tippett et al ²⁰⁰⁷	68(27-41)	59(22-37)	75.2 ^M	73.0 ^M	12.2 ^M	11.6 ^M	18.6	-	Set 1(34-34)MC Set 2(12-12)MC Set 3(14-14)MC Set 4(13-13)MC	(1,2,4)Fam (1,2,3)LF (2)VC (3)AoA, NA (3,4)NAc
Moreno- Martinez et al 2007	32(14-18)	34(17-17)	73.8 ^M	71.7 ^M	7.9 ^M	9.9 ^M	20.5	29.1	(56-56)CP	AoA, Fam, NA, VC, NF
Moreno- Martinez et al 2008	38(16-22)	30(15-15)	74.7 ^M	71.9 ^M	7.6 ^M	9.7 ^M	20.5	29.1	(49-49)CP	AoA, Fam, NA, VC, NF

Note: superscript M, matched for that variable; MC, monochrome line drawings; C, colour stimuli; CP, colour photos; AoA, age of acquisition; Fam, familiarity; Freq, Wall Street Journal Frequency counts; IA, image agreement; Img, imageability; LF, lexical frequency; WL, word length; NA, name agreement; NAc, name accuracy; NF, name frequency; Pro, prototypicality; VC, visual complexity.

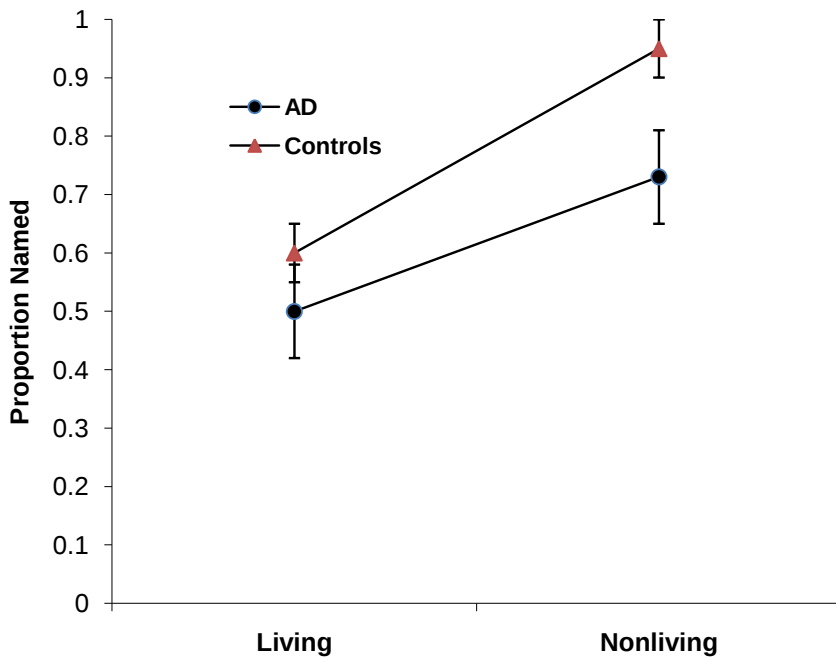


Figure 1. Paradoxical deficit: poorer absolute performance with living ythan nonliving things, but, performance is actually only significantly poorer for 1nonliving things.

Nevertheless, although these authors matched living and nonliving stimuli on levels of word frequency and category typicality, they did not control for other variables such as concept familiarity, visual complexity and age-of acquisition, and, as we will discuss, these variables co-vary strongly with the living/nonliving distinction (Funnell & Sheridan, 1992; Stewart, Parkin, & Hunkin, 1992). Indeed, in a later study, Tippet, Grossman, and Farah (1996) confirmed the findings of Silveri and colleagues using an identical set of items, but were unable to replicate the living naming impairment in the same patients on a newer set of pictures that were matched across category on a greater number of predictor variables. Tippet et al. (1996) verified that the disproportionate deficit with living things disappeared after controlling across category for familiarity, lexical frequency and visual complexity (which all favoured nonliving things); and thus, concluded that Silveri et al.'s findings resulted from a lack of control of these "nuisance" variables.

Consequently, some have questioned the reliability of category-specific deficits in AD patients, claiming that such effects may be an artefact of uncontrolled confounding psycholinguistic variables. The most frequently examined of these variables are: age of acquisition, familiarity, name agreement, visual complexity and word frequency (see Tables 1 and 2). Crucially, these variables invariably benefit the processing of nonliving over living things, with the latter tending to have greater visual complexity, lower familiarity, lower name frequency, and so on. This 'artefactual' account would predict more category-specific cases for living things, which in fact, has been the case - estimated at 5:1 (Laws & Gale, 2002). Indeed, some earlier studies may have documented living deficits because they did not control for these nuisance variables. This explanation is inevitably limited insofar as it cannot

account for the presence of nonliving deficits in patients. An additional problem for such an account is that recent studies, which have more carefully controlled these variables across category, have still reported the presence of living category deficits (e.g. Zannino, Perri, Carlesimo, Pasqualetti, & Caltagirone, 2002).

The literature reveals a somewhat uneven panorama concerning which nuisance variables have been controlled in studies (see Table 1). Nonetheless, we note that when controlling for one variable (e.g., familiarity) the high multicollinearity between nuisance variables means that the others are often controlled inadvertently. Indeed, a recent meta-analysis found that the number of nuisance variables controlled in a study did not affect the size of category effects (See Laws et al 2007).

SUBJECT VARIABLES AFFECTING CATEGORY-SPECIFICITY: DEMENTIA SEVERITY

AD itself is an heterogeneous and, by definition, degenerative disorder and therefore patient performance must be related to severity of dementia. Indeed, the inconsistency across category specificity studies raises important questions about which factors moderate the occurrence of category-specific impairments in AD patients and, whether they are living or nonliving in nature. Unlike most accounts of category effects, those relating to dementia severity attempt to trace both living and nonliving deficits to a single underlying variable that reflect differences in the level of cognitive impairment (e.g. as measured by naming ability or dementia severity). One hypothesis articulated by Gonnerman, Andersen, Devlin, Kempler, Seidenberg (1997) is that the category-specificity in AD is determined by the overall level of cognitive impairment. According to this idea, patients with relative preservation of semantic memory (i.e. those in the early stages of the disease) are more prone to present nonliving thing deficits. As level of impairment increases over time, however, the category-specific profile reverses: patients will present nonliving thing deficits, although in the context of poor overall naming performance (see Devlin, Gonnerman, Andersen, & Seidenberg, 1998). Although Gonnerman and colleagues reported a pattern of performance in their AD patients consistent with their hypothesis, most other studies have failed to replicate this profile - notably in much larger patient cohorts on more extensive stimulus sets (Garrard, Patterson, Watson, & Hodges, 1998; Moreno-Martínez & Laws, 2008; Zannino et al., 2002; Moreno-Martínez et al., 2008). Despite this, Gonnerman et al's work has emphasised the fact that group analyses may mask important individual variability in category effects.

Table 3 displays the findings from longitudinal and cross-sectional studies of category effects in AD. As expected, the results are varied, but most report a category effect at the individual level and two of the group studies found a category effect at group level, both of which reported a living thing deficit. Gonnerman et al (1997) and Garrard et al (1998, 2001) failed to find a category effect at group level, but individual participants demonstrated both living thing and nonliving thing deficits; the researchers concluded that the net effect was to eliminate the category effect for the group.

In the largest and most comprehensive longitudinal analysis involving 58 AD patients, Garrard et al. (2001) found no interaction between the degree of impairment and category, only a greater vulnerability to the impairment of the living thing categories. Within the model

of anatomical progression of AD of Braak and Braak (1991), Garrard et al. (2001) proposed that the cerebral region affected by the disease is relevant to the type of categorical impairment expressed. In the early stages, AD normally affects temporo-limbic regions (Braak & Braak, 1991); and lesion data suggest that these regions could play a role in the representation of knowledge of living things (Gainotti, 2005). A living thing deficit is therefore more likely to occur in AD (as noted above, the incidence of category deficits is higher, but the severity does not differ), as happens in diseases such as herpes simplex encephalitis which also mainly affect the temporal region (Laws & Sartori, 2005).

Table 3. Longitudinal analyses of AD patients: cross-sectional and longitudinal

	Effect found?	Methodology	Direction	Longitudinal profile
Gonnerman et al, 1997	No ^a Yes ^b	Long & CS	NL and L	Predicted an initial NL
Garrard et al, 1998	No ^a Yes ^b	CS	NL and L	Category effect increases with increasing anomia
Garrard et al, 2001	No	Long & CS	-	Category effect increases with increasing anomia
Zannino et al, 2002	Yes	CS	L	Category effect increases with increasing anomia
Whatmough et al, 2003	Yes	CS	L	Category effect increases with increasing anomia
Cuetos et al, 2008	No	Long 2 patients	-	Change from a LT to a NL ^c
Tippett et al, 2007	Yes&No ^e	CS	L and NL ^f	NL deficit with mild anomia, L deficit with

Notes: ^a at group level, ^b at individual level ^c predicted profile, but not reported, ^d not significant ^e depending on which variables controlled for ^f NL when elderly controls not performing at ceiling

‘Normal’ Category Bias?

Far less attention has focussed on category-specificity from a *normative* viewpoint, i.e. addressing the question of whether a category effect emerges in normal healthy participants. Recent studies directed to examining healthy participants themselves have started to shed important new light upon, and circumscribe the interpretations and investigations of category deficits. Nevertheless, the outcome of these studies has produced some contradictory data. The majority has revealed better and faster naming of living than nonliving things (Brousseau & Buchanan, 2004; Filliter, McMullen & Westwood, 2004; Laws 1999, 2000, 2002, 2003; Laws, Leeson and Gale, 2002a; Laws & Neve 1999; McKenna & Parry, 1994); however, others have reported an advantage for naming nonliving things (Gaffan & Heywood, 1993; Humphreys, Riddoch, & Quinlan, 1988; Laws & Gale 2002). Some of these differences again stem from the lack of matching for nuisance variables across category. Other differences relate to the presentation conditions e.g. some have used speeded presentation, degraded and masked images or colour versus line drawings. Nonetheless, the repeated finding of a *normal*

advantage for naming living things is important because it undermines any notion that living deficits in patients reflect the greater difficulty of naming living things (e.g. as per nuisance variable accounts, which invariably disadvantage the processing of living things).

That these studies show that living things are both faster and better processed by neurologically healthy individuals, might be viewed as quite plausible according to evolutionary explanations (Caramazza & Mahon, 2003; Caramazza & Shelton, 1998). For example, Caramazza and co-workers have proposed that evolutionary pressures have led to the development of specialized neural mechanisms for processing categories whose quick identification could have survival and reproductive advantages for human beings. Accordingly, they suggest that these categories might include animals, fruits/vegetables, conspecifics and, possibly, tools. Laws (2000) argued that if dedicated neural subsystems exist, then we would surely expect such systems to confer *normal* processing advantages for items in those categories. In other words, the findings are precisely what we would predict at least with regard to living things i.e. better/faster processing in healthy individuals. Future studies need to address whether similar speed/accuracy advantages exist for tools, faces etc). Furthermore, Laws and co-workers argued that such a system could have evolved because living things have a stable physical appearance which may have contributed to the evolution of a specialised processing system (Laws & Neve, 1999; Turnbull & Laws 2000). By contrast, nonliving things have several characteristics that make the development of such a specialised neural system almost impossible. For example, nonliving things have far less predictable physical structures. Rather, in the case of nonliving things, the link between the appearance and the function of the object is aesthetic (rather than necessary). Also, the sheer pace at which technology changes means that man-made items would not maintain a sufficiently stable physical appearance for evolution to adapt systems for their processing (Gale, Laws, Frank, & Leeson, 2003; Laws & Neve, 1999; Turnbull & Laws, 2000).

Gender

Reports of an interaction between the direction of category-specific effects and sex have been associated with various pathologies, including AD (for reviews, see Gainotti 2005; Laiacona, Barbarotto & Capitani, 2006). In a case study analysis of 26 AD patients, Laiacona, Barbarotto, and Capitani (1998) found that eight patients (7 males) showed a deficit for the subcategories of animals, fruits and vegetables, while 3 others (all females) showed a deficit with the nonliving thing subcategories of tools, furniture and vehicles.

Furthermore, neurologically healthy individuals show a similar interaction between sex and category. McKenna and Parry (1994) found that healthy females named nonliving things less accurately. Similarly, Laws and colleagues (Laws, 1999, Laws & Neve, 1999) found that males were faster and better at naming nonliving than living things, while females showed the opposite. Using category fluency tasks, Capitani, Laiacona, and Barbarotto (1999) found that healthy females outperformed males at producing the names of fruits, while men showed a better performance with tools. Laws (2002) confirmed the latter fluency findings in a large sample of 300 men and 300 women. Barbarotto, Laiacona, Macchi, and Capitani (2002) report better performance of women with natural subcategories of fruits and vegetables, and a better performance of men with nonliving thing subcategories of vehicles and furniture. Furthermore, a recent review of case studies by Capitani, Laiacona, Mahon, and Caramazza

(2003) concluded that (i) males show category dissociations more frequently than females and, (ii) all the case studies that reported a greater impairment of fruits and vegetables relative to animals, were male patients.

Two explanations have been proposed to account for this finding: one that emphasises different familiarity profiles across the sexes and the other emphasises an evolutionary account. The familiarity proposal suggests that living/nonliving asymmetries largely reflect females being more familiar with plant categories, i.e. fruits, herbs and vegetation (e.g. Albanese, Capitani, Barbarotto, & Laiacona 2000). Evolutionary proposals suggest the existence of selection pressures that, throughout the generations, could have differently affected women and men owing to their different social roles: women mostly specialised in gathering plant type food and men in hunting animals. Consequently, speculative arguments propose that men and women have developed different specialized brain subsystem to process items from their respective critical categories. Currently, the evidence fails to distinguish between these two accounts of sex-linked divergences; however, independently of the possible origin of these asymmetries, future studies of category-specificity should use sex-matched samples or try to control for the possible influence of this important factor.

By contrast, the recent meta-analysis of category-specific effects in AD patients by Laws et al (2007) revealed that the proportion of female patients had a strong influence on the effect sizes for naming living and nonliving things - with higher proportions of females leading to worse naming in both categories. In this context, several studies in the 1990s alluded to the fact that compared to men with equivalent AD severity; female AD patients manifest greater deficits on tasks of semantic memory (Buckwalter, Sobel, Dunn, Diz, & Henderson, 1993; Henderson & Buckwalter, 1994; McPherson, Back, Buckwalter, & Cummings, 1999; Ripich, Pettrill, Whitehouse, & Ziol, 1995). In particular, women show poorer confrontation naming (Buckwalter et al., 1996; Henderson & Buckwalter, 1994; McPherson et al., 1999; Ripich et al., 1995) and category fluency, but not letter fluency (Henderson & Buckwalter, 1994; Ripich et al., 1995). In a recent direct analysis of this sex difference, Moreno- Martínez, Laws and Schulz (2008) compared semantic category fluency across 7 living and 7 nonliving categories in 61 AD patients (28 male and 33 female) and 36 (18 male, 18 female) young and 36 elderly (17 male 19 female) controls. While the healthy young controls showed no sex differences, the healthy elderly controls showed some significant sex-stereotyped fluency advantages e.g. females for flowers, vegetables, kitchen utensils. By contrast, after controlling for dementia severity as rated by the Mini Mental State Examination, male AD patients outperformed females in 13/14 fluency categories (significantly for insects, trees, animals, vehicles, tools and musical instruments).

Importantly, the language-based sex differences in AD patients remain after controlling for the effects of age, education, and duration of illness (Buckwalter et al., 1993, 1996; Henderson & Buckwalter, 1994; Ripich et al., 1995). In the context, it is worth noting research on the apolipoprotein E (APOE: 19q13.2) $\epsilon 4$ allele, which represents an established genetic risk factor for AD (Corder et al., 1993), and in the healthy older population, those with the $\epsilon 4$ allele also present with poorer cognitive performance, especially on memory tests (Soininen & Riekkinen, 1996). Although findings remain contentious, the APOE genotype has been associated with: a greater probability for developing AD in women than men (Bretsky et al, 1999; Gomez et al, 1996; Payami et al, 1996); a more pronounced effect on cognitive performance in the general population of women than men (Bartres-Faz et al, 2002;

Hymen et al, 1996); and may also impact on hippocampal atrophy in female AD sufferers (Fleisher et al, 2005). These findings are consistent with a relatively greater semantic and verbal impairment in female AD sufferers i.e. different from and beyond greater than any pre-existing sex differences in cognition (Heun & Kockler, 2002).

Controls, Ceilings and Categories

The vast majority of studies examining category-specificity have used simple line-drawn stimuli. Indeed, approximately 90% of the studies examining category-specific effects have employed monochrome line drawings (typically from the Snodgrass & Vanderwart 1980 corpus: see Laws, Gale, Leeson & Crawford, 2005). Given that the majority of items featured in this corpus are easily identifiable by healthy controls, many studies examining category effects in AD patients have been confounded by at -or near to- ceiling in the controls (Laws, 2005; see Table 4).

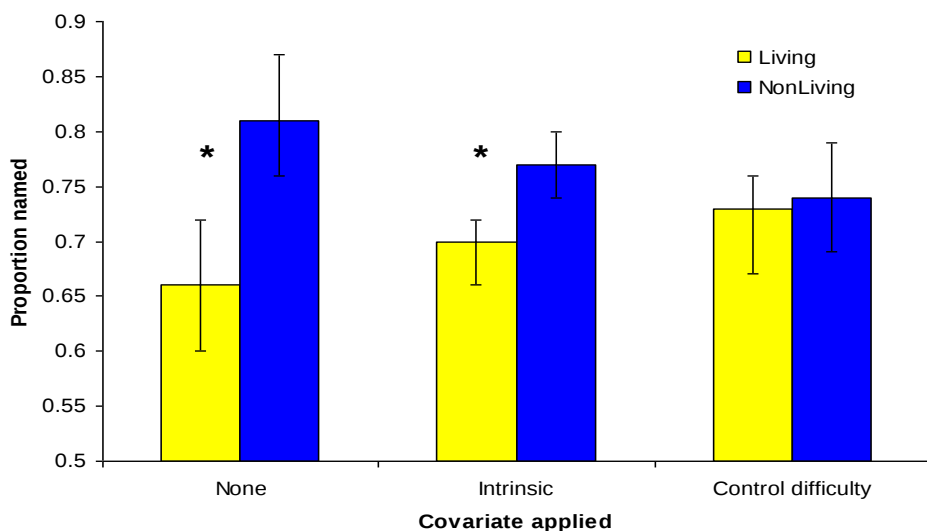
Table 4. Living and nonliving naming levels for healthy controls in studies of category-specificity in Alzheimer's Patients

Study	Living Mean (%)	Nonliving Mean (%)
Silveri et al. (1991)	99.8	99.8
Mauri et al. (1994)	98	98
Montanes et al. (1995)	96	97
Gonnerman et al. (1997) Exp 1	99.4	99.4
Gonnerman et al. (1997) Exp 2	97	97.2
Garrard et al. (1998)	93	97
Grossman et al. (1998)	89.9	91.2
Garrard et al. (2001)	90.5	93.3
Fung et al. (2001)	81	81
Zannino et al. (2002)	98	98.3
Laws et al. (2003)	95.6	96.6
Perri et al. (2003)	93	95
Whatmough et al. (2003)	82.6	82.5
Laws et al. (2005) Exp 1	95.6	94.6
Laws et al. (2005) Exp 2a	95.7	95.9
Laws et al. (2005) Exp 2b	74.3	74.9
Laws et al. (in press)	92.2	91.8
Moreno-Martínez et al. (2008)	89	97
Gale et al. (in press)	95	96

Even after conducting transformations of data, typical parametric (and nonparametric) analyses may be inappropriate for data that have heavily skewed distributions, unequal variances across groups, and/or multiple zero errors. Four studies have attempted to minimize ceiling effects in controls through the use of more difficult stimuli (Fung et al., 2001; Laws et al., 2005; Tippet et al., 2007; Whatmough, Chertkow, Murtha, Templeman, Babins, & Kelner, 2003). Laws and colleagues (Moreno-Martínez and Laws 2007, 2008; Gale, Irvine,

Laws & Ferrisey, in press) proposed another strategy, which involves the use of bootstrap statistical techniques. Bootstrap statistical methods require far fewer assumptions than traditional parametric tests regarding data distributions; and are advisable in circumstances where many zero data points occur (e.g. controls scoring very highly or patients very lowly: see Delucchi & Bostrom, 2004). With bootstrap techniques, a relevant test statistic (t or F etc) is computed for n bootstrap samples, i.e. n permutations of the original group data. When this occurs *with replacement*, a data point goes back into the sampling pool potentially to be redrawn numerous times. After many permutations (e.g. 1000) a more normal distribution of *test statistics* emerges as opposed to the abnormally distributed original *data points*. The value of the original statistic is then compared to the new distribution and declared significant at, for example, the 0.05 level, if it is among the most extreme 5% of cases.

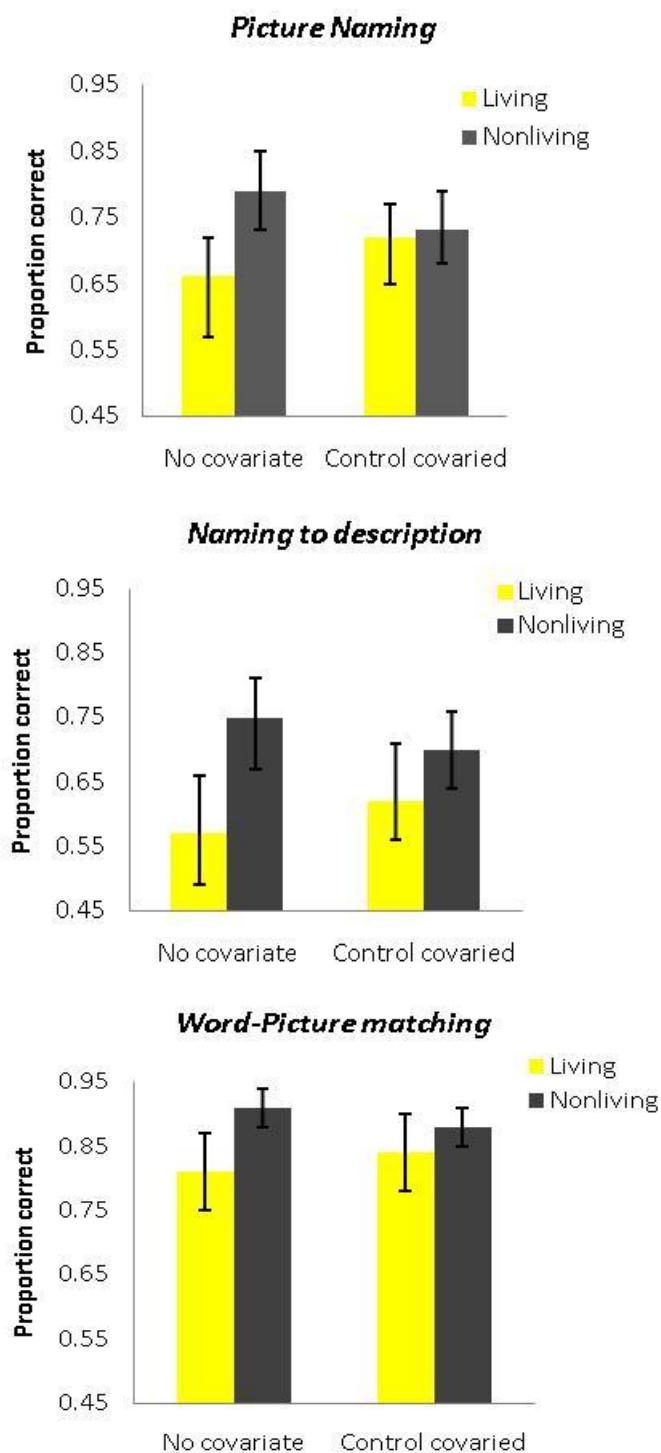
Moreno-Martínez and Laws (2007) compared naming in three conditions: without covarying any variables, covarying of nuisance variables and covarying the healthy control performance (in ANCOVAs). Analysis of 1000 bootstrap samples showed that even with covarying the effects of nuisance variables, a significant category effect for living things persisted. By contrast, analysis of 1000 bootstrap ANCOVAs covarying the *normal difficulty index* (that is, the level of naming by controls on the same items), the category effect disappeared (see Figure 2). In other words, although not explicable in terms of nuisance variables, the category effect was no greater than would be predicted from the performance of healthy controls. In an extension of this work, Moreno-Martínez & Laws (2008) showed that the category effect in AD patients disappeared on several semantic tasks (picture naming, naming to description and word-picture matching) after using 1000 bootstrap ANCOVAs to control for the *difficulty index* covariate (see Figure 3). The authors interpreted these findings to mean that while AD patients show significant semantic memory impairment, the level of category-specificity is qualitatively similar to that found in healthy elderly individuals.



Error bars represent 95%CI from 1000 bootstrap resamples.

Asterisks (*) represent significant differences.

Figure 2. Category naming performance in Alzheimer's patients before and after covarying intrinsic variables and level of difficulty in healthy controls.



* Bars are 95% Confidence intervals.

Figure 3. Category performance in AD patients (n=38) before and after covarying naming difficulty in neurologically healthy controls (n=30).

Finally, Gale, Irvine, Laws & Ferrisey (in press) again using bootstrapping, but this time with hierarchical regression analyses. Estimating how much of the naming variance in 28 AD patients was uniquely attributable to different variables, Gale et al reported that nuisance variables uniquely accounted for almost 40% of the variance. After controlling for nuisance variables, a *difficulty index* based on performance in 24 neurologically healthy controls accounted for a further 36% of the variance. Finally, category accounted for less than one-tenth of these figures - at approximately 3%. Although the later indicates that category has a relatively small impact, it was significant, suggesting that a small amount of variance in AD naming is uniquely attributable to category i.e. beyond that accountable by nuisance variables or control performance.

SUMMARY

AD patients show undoubted semantic memory impairment, which probably reflects the fact that, even in the early stages, the disease process affects the temporal lobes. Although most studies have documented living thing category deficits, the findings are contentious. In particular, certain item-based and subject-based variables artefactually contribute to some of the differences. For example, the failure to control confounding nuisance variables in earlier studies may have artificially inflated the documentation of living thing deficits; however, later better controlled research clearly shows that category effects in AD persist after controlling for the major nuisance variables. Critically, two recent studies have shown that the category naming performance of healthy controls accounts for much of the variance in naming by AD patients. In other words, category effects in AD patients are an exaggeration of the category processing biases shown by neurologically healthy participants. This does not eradicate the existence of category effects in semantics, since recent work estimates that a small (at least 3%), but significant amount of the variance in AD naming is attributable to category (i.e. above and beyond the influence of all nuisance variables and the difficulty level shown by controls). Combined, these studies indicate that the effects in AD patients are quantitatively, though not qualitatively, altered because of their neural degeneration. Finally, the apparent influence of sex requires further exploration. As far as the category differences between men and women are concerned, the roles of evolution and familiarity remain to be ascertained. In a somewhat opposing vein is the intriguing evidence that female AD patients show overall worse semantic memory performance than males. We speculate that this female disadvantage may be underpinned by the apolipoprotein E (APOE) $\epsilon 4$ allele, which is associated with a greater probability for developing AD in women and may impact more on the cognitive performance of healthy women than men.

ACKNOWLEDGMENTS

FJMM's work was supported by a postdoctoral research award from the Spanish Ministry of Education and Science (*programa José Castillejo* -JC2007-00248).

REFERENCES

- Adlam, A. R., Bozeat, S., Arnold, R., Watson, P., & Hodges, J. R. (2006). Semantic knowledge in mild cognitive impairment and mild Alzheimer's disease. *Cortex*, 42, 675-684.
- Albanese E., (2007). The "hidden" semantic category dissociation in mild-moderate Alzheimer's disease patients. *Neuropsychologia*, 45, 639-643.
- Albanese E., Capitani E., Barbarotto R., & Laiacona, M. (2000). Semantic category dissociations, familiarity and gender. *Cortex*, 36, 733-746.
- Alzheimer's Association (2007). Alzheimer's Disease Facts and Figures 2007.
- Barbarotto, R., Laiacona, M., Macchi, V., & Capitani, E. (2002). Picture reality decision, semantic categories and gender: A new set of pictures with norms and an experimental study. *Neuropsychologia*, 40, 1637-1653.
- Bartres-Faz, D., Junque, C., Moral, P., Lopez-Alomar, A., Sanchez-Aldeguer, J., & Clemente, I. C. (2002). Apolipoprotein E gender effects on cognitive performance in age-associated memory impairment. *Journal of Neuropsychiatry and Clinical Neurosciences*, 14, 80-83.
- Bayles, K.A., & Tomoeda, C.K. (1983). Confrontation naming impairment in dementia. *Brain and Language*, 19, 98-114.
- Bayles, K.A., Tomoeda, C.K., & Trosset, M.W. (1990). Naming and categorical knowledge in Alzheimer's disease: the process of semantic memory deterioration. *Brain and Language*, 39, 498-510.
- Braak, H., & Braak, E. (1991). Neuropathological staging of Alzheimer-related changes. *Acta Neuropathologica*, 82, 239-259.
- Braak, H., & Braak, E. (1996) Evolution of the neuropathology of Alzheimer's disease. *Acta Neurologica Scandinavica*, 93, 3-12.
- Bretsky, P. M., Buckwalter, J. G., Seeman, T. E., Miller, C. A., Poirier, J., Schellenberg, G. D., Finch, C. E., & Henderson, V. W. (1999). Evidence for an interaction between apolipoprotein E genotype, gender, and Alzheimer disease. *Alzheimer Disease and Associated Disorders*, 13, 216-221.
- Buckwalter, J.G., Rizzo, A.A., McCleary, R., Shankle, R., Dick, M., & Henderson, V.W. (1996). Gender comparisons of cognitive performances among vascular dementia, Alzheimer disease, and older adults without dementia. *Archives of Neurology*, 53, 436-439.
- Buckwalter, J.G., Sobel, E., Dunn, M.E., Diz, M.M., & Henderson, V.W. (1993). Gender differences on a brief measure of cognitive functioning in Alzheimer's disease. *Archives of Neurology*, 50, 757-760.
- Capitani, E., Laiacona, M., & Barbarotto, R. (1999). Gender affects word retrieval of certain categories in semantic fluency tasks. *Cortex*, 35, 273-278.
- Capitani, E., Laiacona, M., Mahon, B., & Caramazza, A. (2003). What are the facts of semantic category-specific deficits? A critical review of the clinical evidence. *Cognitive Neuropsychology*, 20, 213-261.
- Caramazza, A., & Mahon, B.Z. (2003). The organization of conceptual knowledge: the evidence from category-specific semantic deficits. *Trends in Cognitive Sciences*, 7, 354-361.

- Caramazza, A., & Shelton, J.R. (1998) Domain-specific knowledge systems in the brain: The animate- inanimate distinction. *Journal of Cognitive Neuroscience*, 10, 1-34.
- Chertkow, H., & Bub, D. (1990). Semantic memory loss in dementia of Alzheimer's type. *Brain*, 113, 397-417.
- Corder, E.H., Saunders, A.M., Strittmatter, W.J., Schmechel, D.E., Gaskell, P.C., Small, G.W., Roses, A.D., Haines, J.L. & Pericckvance, M.A. Gene dose of apolipoprotein E type 4 allele and the risk of Alzheimer's disease in late onset families. *Science*, 261: 921–923, 1993.
- Cuetos, F., Rosci, C., Laiacona, M., & Capitani, E. (2008). Different variables predict anomia in different subjects: A longitudinal study of two Alzheimer's patients. *Neuropsychologia*, 46, 249-260.
- Daum, I., Riesch, G., Sartori, G., & Birbaumer, N. (1996). Semantic memory impairment in Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology*, 18, 648-665.
- Deluchhi, K.L., & Bostrom, A. (2004). Methods for analysis of skewed data distributions in psychiatric clinical studies: Working with many zero values. *American Journal of Psychiatry*, 161, 1159-1168.
- Devlin, J.T., Gonnerman, L.M., Andersen, E.S. & Seidenberg, M.S. (1998). Category-specific semantic deficits in focal and widespread brain damage: A computational account. *Journal of Cognitive Neuroscience*, 10, 77-94.
- Done, D. J., & Gale, T.M. (1997). Attribute verification in dementia of Alzheimer type: evidence for the preservation of distributed concept knowledge. *Cognitive Neuropsychology*, 14, 547-572.
- Durrant-Peatfield, M., Tyler, L.K., Moss, H., & Levy, J.P. (1997). The distinctiveness of form and function in category structure: A connectionist model. In: M.G. Shafto & P. Langley (Eds.), *Proceedings of the Nineteenth Annual Conference of the Cognitive Science Society*, Mahwah, NJ: Erlbaum (pps 193-198).
- Fleisher, A., Grundman, M., Jack, C. R., Petersen, R. C., Taylor, C. Kim, H. T., Schiller, D. H. B., Bagwell, V., Sencakova, D., Weiner, M. F., DeCarli, C., DeKosky, S. T., van Dyck, C. H., & Thal, L. J. (2005). Sex, apolipoprotein E epsilon 4 status, and hippocampal volume in mild cognitive impairment. *Archives of Neurology*, 62, 953-957.
- Fodor, J.A. (1983). *Modularity of Mind: An Essay on Faculty Psychology*. Cambridge, Mass.: MIT Press.
- Fung, T.D., Chertkow, H. Murtha, S., Whatmough, C., Peloquin, L., Whitehead, V., & Templeman, F.D. (2001). The spectrum of category effects in object and action knowledge in dementia of the Alzheimer's type. *Neuropsychology*, 15, 371-379.
- Funnell, E., & Sheridan, J. (1992). Categories of knowledge: unfamiliar aspects of living and nonliving things. *Cognitive Neuropsychology*, 9, 135-153.
- Gainotti, G. (2000). What the locus of brain lesion tell us about the nature of the cognitive defect underlying category-specific disorders: a review. *Cortex*, 36, 539-559.
- Gainotti, G. (2005). The influence of gender and lesion location on naming disorders for animals, plants and artifacts. *Neuropsychologia*, 43, 1633-1644.
- Gainotti, G., & Silveri, M.C. (1996). Cognitive and Anatomical Locus of Lesion in a Patient with a Category-specific Semantic Impairment for Living Beings. *Cognitive Neuropsychology*, 13, 357-389.

- Gale, T.M., Laws, K.R., Frank R.J. & Leeson, V.C. (2003). Basic-level visual similarity and category specificity. *Brain and Cognition*, 53, 229-231.
- Garrard, P., Lambon-Ralph, M. A., Patterson, K., Pratt, K. H., & Hodges, J. R. (2005). Semantic feature knowledge and picture naming in dementia of Alzheimer's type: A new approach. *Brain and Language*, 93, 79-94.
- Garrard, P., Lambon-Ralph, M.A, Watson, P.C., Powis, J., Patterson, K., & Hodges, J.R. (2001). Longitudinal profiles of semantic memory impairment for living and non-living concepts in dementia of Alzheimer's type. *Journal of Cognitive Neuroscience*, 13, 892-909.
- Garrard, P., Patterson, K., Watson, P.C., & Hodges, J.R. (1998). Category specific semantic loss in dementia of Alzheimer's type. *Brain*, 121, 633-646.
- Gomez-Isla, T., West, H.L., Rebeck, G.W., Harr, S.D., Growdon, J.H., Locascio JJ, Perls, T.T., Lipsitz, L.A. & Hyman, B.T. Clinical and pathological correlates of apolipoprotein E $\epsilon 4$ in Alzheimer's disease. *Annals of Neurology*, 39: 62-70, 1996.
- Gonnerman, L.M, Andersen, E.S., Devlin, J.T., Kempler, D., & Seidenberg, M.S. (1997). Double Dissociation of semantic categories in Alzheimer's disease. *Brain and Language*, 57, 254-279.
- Grossman, M., Robinson, K., Biassou, N., White-Devine, T., & D'Esposito, M.D. (1998). Semantic memory in Alzheimer's disease: representativeness, ontologic category, and material. *Neuropsychology*, 12, 34-42.
- Hanyu, H., Shimizu, S., Tanaka, Y., Takasaki, M., Koizumi, K., & Abe K. (2004). Differences in regional cerebral blood flow patterns in male versus female patients with Alzheimer disease. *American Journal of Neuroradiology*, 25, 1199-1204.
- Harley, T.A, & Grant, F. (2004). The role of functional and perceptual attributes: evidence from picture naming in dementia. *Brain and Language*, 91, 223-234.
- Henderson, V.W., & Buckwalter, J.G. (1994). Cognitive deficits of men and women with Alzheimer's disease. *Neurology*, 44, 90-96.
- Heun, R., & Kockler, M. (2002). Gender differences in the cognitive impairment in Alzheimer's disease. *Archives of Womens Mental Health*, 4, 129-137.
- Hodges, J.R., Graham, N., & Patterson, K.A. (1995). Charting the progression in semantic dementia: Implications for the organization of semantic memory. *Memory*, 3, 463-496.
- Hodges, J.R., Salmon, D.P., & Butters, N. (1991). The nature of the naming deficit in Alzheimer's and Huntington's disease. *Brain*, 114, 1547-1558.
- Hodges, J.R., Salmon, D., & Butters, N. (1992). Semantic memory impairment in Alzheimer's disease: Failure of access or degraded knowledge? *Neuropsychologia*, 30, 301-314.
- Humphreys, G.W., Riddoch, M.J., & Quinlan, P.T. (1988). Cascade processes in picture identification. *Cognitive Neuropsychology*, 5, 67-103.
- Hyman B.T., Gomezisla T., Briggs, M., Chung, H., Nichols, S., Kohout, F., and Wallace, R. Apolipoprotein E and cognitive change in an elderly population. *Annals of Neurology*, 40: 55-66, 1996. Joubert, S., Felician, O., Barbeau, E.J., Didic, M., Poncet, M., Ceccaldi, M. (2008). Patterns of semantic memory impairment in Mild Cognitive Impairment. *Behavioural Neurology* 19, 35-40.
- Laiacina, M., Barbarotto, R., & Capitani, E. (1998). Semantic category dissociations in naming: is there a gender effect in Alzheimer's disease. *Neuropsychologia*, 36, 407-419.

- Laiacona, M., Barbarotto, R., & Capitani, E. (2006). Human evolution and the brain representation of semantic knowledge: is there a role for sex differences? *Evolution and Human Behavior*, 27, 158-168.
- Lambon Ralph, M. A., Patterson, K., & Hodges, J. R. (1997). The relationship between naming and semantic knowledge for different categories in dementia of Alzheimer's type. *Neuropsychologia*, 35, 1251-1260.
- Laws, K.R. (1999). Gender affects naming latencies for living and non-living things: Implications for familiarity. *Cortex*, 35, 729-733.
- Laws, K.R. (2000). Category-specific naming errors in normal subjects: The influence of evolution and experience. *Brain and Language*, 75, 123-133.
- Laws, K.R. (2002) Category-specificity and imagery vividness in different modalities. *Brain and Cognition*, 48, 418-420.
- Laws, K.R. (2003) Sex differences in lexical size across semantic categories. *Personality and Individual Differences*, 36, 23-32.
- Laws, K.R. (2005). "Illusions of normality": a methodological critique of category specific naming. *Cortex*, 41, 842-851.
- Laws, K.R., Adlington, R.L., Gale, T.M., Moreno-Martínez, F.J., Sartori, G. (2007). A meta-analytic review of category naming in Alzheimer's disease. *Neuropsychologia*, 45, 2674-2682.
- Laws, K.R., Crawford, J.R., Gnoato, F., & Sartori, G. (2007). A predominance of category deficits for living things in Alzheimer's disease and Lewy Body dementia. *Journal of the International Neuropsychological Society*, 13, 401-409.
- Laws, K.R., Gale, T.M., Leeson, V.C., & Crawford, J.R. (2005). When is category-specific in Alzheimer's disease. *Cortex*, 41, 452-463.
- Laws, K.R., Gale, T.M., Leeson, V.C., & Davey, N. (2003). The influence of surface and edge-based visual similarity on object recognition. *Brain and Cognition*, 53, 232-234.
- Laws, K.R., Leeson, V.C., & Gale, T.M. (2002a). The effect of 'masking' on picture naming latencies. *Cortex*, 38, 137-147.
- Laws, K.R., Leeson, V.C., & Gale, T.M. (2002b). A domain-specific deficit for foodstuffs in patients with Alzheimer's disease. *Journal of the International Neuropsychological Society*, 8, 956-957.
- Laws, K.R., & Neve, C. (1999). A "normal" category-specific advantage for naming living things. *Neuropsychologia*, 37, 1263-69.
- Laws, K.R., & Sartori, G. (2005). Category deficits and paradoxical dissociations in Alzheimer's disease and herpes simplex encephalitis. *Journal of Cognitive Neuroscience*, 17, 1453-1459.
- Martin, A., & Fedio, P. (1983). Word production and comprehension in Alzheimer's disease. The breakdown of semantic knowledge. *Brain and Language*, 19, 124-141.
- McCarthy, R. A., & Warrington, E. K. (1992). Actors but not scripts: The dissociation of people and events in retrograde amnesia. *Neuropsychologia*, 30, 633-644.
- McPherson, S., Back, C., Buckwalter, J.G., Cummings, J.L. (1999). Gender-related cognitive deficits in Alzheimer's disease. *International Psychogeriatrics*, 11, 117-122.
- Mauri, A., Daum, I., Sartori, G., & Riesch, G. (1994). Category-specific semantic impairment in Alzheimer's disease and temporal lobe dysfunction: A comparative study. *Journal of Clinical and Experimental Neuropsychology*, 16, 689-701.

- McKenna, P., & Parry, R. (1994). Category-specificity in the naming of natural and man-made objects. *Neuropsychological Rehabilitation*, 4, 255-281.
- Mondini, S., & Semenza, C. (2006). How Berlusconi keeps his face: a neuropsychological study in a case of semantic dementia. *Cortex*, 42, 332-335.
- Montanes, P., Goldblum, M.C., & Boller, F. (1995). The naming impairment of living and nonliving items in Alzheimer's disease. *Journal of the International Neuropsychological Society*, 1, 39-48.
- Mooney, C.Z., & Duval, R.D. (1993). Bootstrapping: A non-parametric approach to statistical inference. Beverly Hills: Sage Publications.
- Moreno-Martínez, F.J., & Laws, R.K. (2007). An attenuation of the 'normal' category effect in patients with Alzheimer's disease: A review and bootstrap analysis. *Brain and Cognition*, 63, 136-142.
- Moreno-Martínez, F.J., Laws, K.R (2008). No category-specificity in Alzheimer's disease: a normal aging effect. *Neuropsychology*, 22, 485-490
- Moreno-Martínez, F.J., Laws, K.R & Goñi-Imízcoz, M. (2008). The Longitudinal Neurodegenerative Impact of Alzheimer's Disease on Picture Naming . In 'Alzheimer's Disease in the Middle-Aged' (Ed: HS Jeong).
- Moreno-Martínez, F.J., Laws, K.R & Schulz J (2008). The impact of dementia, age and sex on category fluency: greater deficits in women with Alzheimer's disease. *Cortex*, 44, 1256-1264.
- Nebes, R. D. (1989). Semantic memory in Alzheimer's disease. *Psychological Bulletin*, 106, 377-394.
- Payami, H., Zarepari, S., Montee, K. R., Sexton, G. J., Kaye, J. A., Bird, T. D., Yu, C. E., Wijsman, E. M., Heston, L. L., Litt, M., & Schellenberg, G. D. (1996). Gender differences in Apolipoprotein E-associated risk for familial Alzheimer disease: A possible clue to the higher incidence of Alzheimer disease in women. *American Journal of Human Genetics*, 58, 803-811.
- Pérez, .M. A., & Navalón, C. (2003). Spanish norms for 290 drawings. Agreement in name, concordance, familiarity, visual complexity and variability of the image. *Psicológica*, 24, 215-241.
- Perri, R., Carlesimo, G. A., Zannino, G. D., Mauri, M., Muolo, B., Pettenati, C., & Caltagirone, C. (2003). Intentional and automatic measures of specific-category effect in the semantic impairment of patients with Alzheimer's disease. *Neuropsychologia*, 41, 1509-1522.
- Ripich, D.N., Petrill, S.A., Whitehouse, P.J., & Ziolo, E.W. (1995). Gender differences in language of AD patients: a longitudinal study. *Neurology*, 45, 299-302.
- Salmon, D.P., Butters, N., & Chan, A.S. (1999). The deterioration of semantic memory in Alzheimer's disease. *Canadian Journal of Experimental Psychology*, 53, 108-116.
- Silveri, M. C., Cappa, A., Mariotti, P., & Puopolo, M. (2002). Naming in patients with Alzheimer's disease: Influence of age of acquisition and categorical effects. *Journal of Clinical and Experimental Neuropsychology*, 24, 755-764.
- Silveri, M.C., Daniele, A., Giustolisi, L., & Gainotti, G. (1991). Dissociation between knowledge of living and nonliving things in dementia of the Alzheimer type. *Neurology*, 41, 545-546.

- Snodgrass, J. G., & Vanderwart, M. (1980). A standardised set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6, 174-215.
- Snowden, J.S., Goulding P.J. and Neary D., (1989). Semantic dementia: A form of circumscribed cerebral atrophy, *Behavioral Neurology* 2, 167-182.
- Snowden, J., Griffiths, H., & Neary, D. (1994). Semantic dementia – autobiographical contribution to preservation of meaning. *Cognitive Neuropsychology*, 11, 265-288.
- Soininen, H. S., & Riekkinen, P. J. (1996). Apolipoprotein E, memory and Alzheimer's disease. *Trends in Neuroscience*, 19, 224-228.
- Stewart, F., Parkin, A.J., & Hunkin, N.M. (1992). Naming impairment following recovery from Herpes Simplex Encephalitis: Category-specific? *Quarterly Journal of Experimental Psychology*, 44, 261-284.
- Tippett, L.J., Grossman, M., & Farah, M.J. (1996). The semantic memory impairment of Alzheimer's disease: Category-specific? *Cortex*, 32, 143-153.
- Tippett, L.J., Meier, S.L., Blackwood, K., & Diaz-Asper, C. (2007). Category specific deficits in Alzheimer's disease: fact or artefact? *Cortex*, 43, 907-920
- Tulving, E. (1972). Episodic and semantic memory. In E. Tulving and W. Donaldson (eds.) *Organisation of Memory*, Academic Press, London.
- Turnbull, O.H., & Laws, K.R. (2000) Loss of stored knowledge of object structure: Implications for "category-specific" deficits. *Cognitive Neuropsychology* 17, 365-389.
- Tyler, L.K., Moss, H.E., Durrant-Peatfield, M.R., & Levy, P (2000). Conceptual structure and the structure of concepts: A distributed account of category-specific deficits. *Brain and Language*, 75, 195-231.
- Vogel, A., Gade, A., Stokolm, J., & Waldemar, G. (2005). Semantic memory impairment in the earliest phases of Alzheimer's disease. *Dementia and Geriatric Cognitive Disorders*, 19, 75-81.
- Warrington, E.K., & Shallice, T. (1984). Category specific semantic impairments. *Brain*, 107, 829-854.
- Whatmough, C., Chertkow, H., Murtha, S. Templeman, D., Babins, L., & Kelner, N. (2003). The semantic category effect increases with worsening anomia in Alzheimer's type dementia. *Brain and Language*, 84, 134-147.
- Zannino, G., D, Perri, R., Carlesimo, G., A, Pasqualetti, P., & Caltagirone, C. (2002). Category-specific impairment in patients with Alzheimer's disease as a function of disease severity: a cross-sectional investigation. *Neuropsychologia* 40, 2268-2279.
- Zannino, G.D., Perri, R., Pasqualetti, P., Caltagirone, C., & Carlesimo, G.A. (2006). Category-specific semantic deficit in Alzheimer's patients: the role of semantic distance. *Neuropsychologia*, 44, 52-61.
- Zannino, G.D., Perri, R., Caltagirone, C., Carlesimo, G.A (2007). Category-specific naming deficit in Alzheimer's disease: The effect of a display by domain interaction *Neuropsychologia* 45, 1832-1839.

Chapter 18

PREVERBAL CATEGORY FORMATION: THE ROLE OF REAL-WORLD EXPERIENCE

Birgit Träuble^{*}, Lysett Babocsai and Sabina Pauen

University of Heidelberg, Germany

ABSTRACT

Studies on categorization using the object-examination task (OET) show that infants carry out a global-to-basic level shift in their second half of their first year of life. What underlies performance in the OET still remains unclear, however. Following one view, infants in an OET activate previously acquired knowledge about real-world exemplars. This suggests that categorization performance in the OET should vary with the amount of experience infants have with real-world exemplars displayed by the experimental material. The present studies test this hypothesis, by comparing the categorization performance of infants who do not have regular contact to cats or dogs (Experiment 1) with the performance of infants who live with a cat or a dog at home (Experiment 2). Analyses based on data from $N = 80$ 9- and 11-month-old infants reveal that 11-month-olds who have experience with cats or dogs make a clear categorical distinction whereas infants without such experiences do not show any categorization response. This set of findings suggests that experience with real-world animals influences performance of infants participating in an OET providing a basic-level contrast within the animate domain.

Keywords: Categorization, Concept formation, Infancy, Object-Examination-Task

This report investigates the role of previously acquired real-world knowledge for category formation at a preverbal age. Without the ability to categorize objects or events, and to store such categorical representations in memory we would never be able to reason about unfamiliar material entities. By identifying a given exemplar as a member of some specific

^{*} University of Heidelberg Hauptstrasse 47-51 D-69117 Heidelberg, Germany Tel. +49 (0)6221 54-7347 Fax +49 (0)6221 54-7326 E-mail: birgit.trauble@psychologie.uni-heidelberg.de

category we apply previously acquired knowledge to make inductive inferences. But how does this ability develop?

Even preverbal infants are able to form a wide variety of categories at different levels of abstraction, as has been demonstrated by a fairly large body of research (e.g. Behl-Chadha, 1996; Eimas & Quinn, 1994; Mandler & McDonough, 1993, 1998a; Pauen, 2000, 2002a, 2002b; Quinn & Eimas, 1996; Quinn & Johnson, 2000; Quinn, Eimas, & Rosenkranz, 1993). Such studies are based on different version of the general *familiarity-preference-for-novelty paradigm*. In this paradigm, infants are first familiarized with a number of exemplars from one category. At test, they receive a new exemplar from the already familiar category and one new exemplar from the contrasting category. If infants pay comparably more attention to the out-of-category exemplar than to the same-category exemplar at test, category discrimination is inferred.

Two versions of this task have been used for testing infants less than one year of age: (1) the visual-fixation tasks (VFT) in which infants look at pairs of 2-D pictures presented pair-wise, and (2) the object-examination task (OET) in which the infant is allowed to play with 3-D models presented in sequence. Whereas looking duration for individual exemplars serves as the dependent measure in the former case, examination duration is used in the latter. Examination is defined as the time, during which infants are concentrating on and inspecting the given object (see Oakes, Madole, & Cohen, 1991; Oakes & Tellinghuisen, 1994). Therefore, it describes a subset of looking time. Even though both tasks are based on the same general paradigm, they have lead to discrepant findings in terms of the onset of category discrimination:

Using the VFT, Eimas and Quinn (1994) showed that infants 3- to 4-months of age form so called basic-level categories of cats that includes novel cats but excludes horses, birds, dogs, and tigers. They also appear to distinguish horses from cats, giraffes, and zebras. In addition, Behl-Chadha (1996) found basic-level category discrimination between tables, chairs, and beds. Referring to such observations, these authors argued that infants detect similarities between the pictures, thereby creating a perceptual representation of the given category during the familiarization phase (Quinn & Eimas, 1996). At test, infants compare the perceptually new within-category exemplar as well as the out-of-category exemplar to the newly established category representation. Because the out-of-category exemplar shares fewer perceptual attributes with the recently formed category than the same-category test exemplar, infants show a looking preference for the former. Consistent with this interpretation is the finding that infants seem more likely to succeed in the VFT when provided with a homogeneous selection of familiarization stimuli than a more heterogeneous set of exemplars during familiarization (Eimas, Quinn & Cowan, 1994; Mareshal & French, 2000; Quinn et al., 1993; Younger & Fearing, 2000).

In apparent contrast to these findings, Quinn & Johnson (2000) report that 2-month-olds form a global category representation for mammals that excludes furniture but still fail to form a basic-level representation for cats that excluded elephants, rabbits, or dogs at this age (see also Younger & Fearing, 2000). This in turn suggests the existence of a “broad-to-narrow shift” in the formation of categories between 2 and 4 months of age. Further support for this claim comes from simulation data of connectionist networks in which specific perceptual features serve as input (e.g., Quinn & Johnson, 2000; Mareshal & French, 2000).

In an attempt to integrate these results, one could argue that very young infants (i.e. 2- to 3-month-olds) who still do not have developed their full visual capacities, form rather broad

categories (e.g. mammals vs. furniture), whereas slightly older ones (i.e. 3-4 months of age) who already have improved vision, find it easier to form rather narrow categories at the basic level (e.g. cats vs. dogs). In any case, it can be assumed that 2- to 4-month-olds have not yet had enough time to acquire large amounts of real-world knowledge about the objects depicted on colour-photos. Hence, it seems plausible to infer that the early success in the VFT primarily bears upon perceptual features of the given experimental material (i.e. information about the appearance of the pictures).

The OET provides a slightly different method to test infant categorization. Infants participating in this kind of task are 6 months of age or older. They receive 3-D toy models to play with rather than pictures to look at. Results obtained with this method have shown that 7- to 9-month-olds can discriminate animals, vehicles, and furniture (Mandler & McDonough, 1993; 1998). At 9 to 11 months of age, categorization was also observed for other superordinate-like categories (animals vs. plants, plants vs. vehicles, and furniture vs. kitchen utensils; see Mandler, 2004 for an overview). Mandler & McDonough (1993) point out that such rather abstract categories do not always match adult categories at the superordinate level. For this reason, the authors prefer the term *global categories*. In addition to global categories, OETs demonstrated discrimination of some basic level categories, such as cars and airplanes or motorcycles within the vehicle domain at 9 to 11 months of age. At the same time, they failed to categorize dogs and fish or dogs and rabbits within the animal domain (Mandler & McDonough, 1993). The only animal-contrasts that elicited a clear categorization response before 11 months of age in the OET were dogs vs. birds (Mandler & McDonough, 1998), and humans vs. other mammals (Pauen, 2000). These results suggest that global categories are discriminated some time earlier and with greater ease than basic-level contrasts. A small longitudinal study conducted by Pauen (2002a) testing infants at the ages of 8 and 12 months confirmed the assumption of a *global-to-basic-level shift*. Even though this general trend seems to parallel the broad-to-narrow shift observed by Quinn and Johnson (2000), it takes place much later (i.e. between 7 and 12 months of age). Hence, a general lack of visual processing capacities can not explain why global categories are discriminated more easily than basic-level categories in an OET.

Alternatively, one could speculate that performance in the OET reflects somewhat different cognitive achievements than performance in the VFT. Mandler (2000a, 2000b, 2004) assumes that – from very early on - infants are able to discriminate objects at various levels of abstraction within a visual task, but that this ability does not reflect how they acquire categories in natural settings. Following her line of arguments, the participation in an OET supports the activation and application of previously acquired real-world knowledge more so than the participation in a VFT does. One of the earliest knowledge-based representations that infants seem to form is the representation of animates (Gelman, 1990; Mandler, 1992a, 1992b; Premack, 1990) which, for instance, includes knowledge that animate objects engage in self-initiated movement, whereas inanimate objects only move in the presence of an external force. Following Mandler, the activation of corresponding knowledge may help even very young infants to treat greatly different looking animals as the same kind of thing (i.e. the representation of a self-moving entity). Towards the end of the first year of life when infants have acquired more experience with real-world objects and different kinds of objects (e.g. different kinds of animal species), preverbal categories become more differentiated, and infants start making basic-level distinctions in the OET.

In sum, visual fixation tasks provide evidence for an early broad-to-narrow shift before 3 or 4 months. The object examination task on the other hand indicates a global-to-basic level shift in the second half of the first year of life. While on-line processes of forming perceptual abstractions during the experimental session may explain the former, the latter seem more likely to involve the activation of previously acquired knowledge. This raises the question whether there is any additional evidence that would support the idea that infants apply real-world knowledge in an OET, and thus help us to clarify whether preverbal infants show purely perception-based, or also knowledge-based category discrimination.

Pauen and colleagues designed corresponding studies. In one of these experiments, Pauen (2002b) systematically varied the perceptual similarity between and within the global categories of animals and furniture, while keeping the conceptual similarities and differences associated with the presented exemplars equal. The author found that 11-month-old infants showed highly comparable performance in both conditions. This finding is consistent with the knowledge-based view, but not with the perception-based view. In yet another study, Träuble and Pauen (2007) tested categorization performance, using artificial stimuli that could either be grouped according to overall similarity or according to similarity in one functionally relevant part. Without knowing the functional use of that specific object part, infants categorized the objects according to overall similarity but not part similarity in an OET. After having seen the experimenter demonstrate the functional use of the critical part, however, infants categorized the identical set of stimuli according to part similarity. When the same actions were performed but without producing any effect (i.e. without revealing functional meaning), infants failed to categorize according to the critical part. This set of findings suggests that infants extracted different properties depending on their experimentally manipulated experience with the functional properties of the given set of stimuli.

One great advantage of such studies is that the experimental material has systematically been designed to test the relevance of features related to either the appearance, or the conceptual meaning of objects. One great disadvantage, however, concerns the fact that the material is highly artificial, thus leaving the question how infants categorize objects in the real world unanswered. Since this is what we really wanted to know, we had to find a way to test whether participation in an OET activates previously acquired real-world knowledge (i.e., everyday experiences, concerning exemplars of natural categories). In an attempt to design a corresponding study, we tested 9- and 11-month-old infants' categorization of cats versus dogs, this time not varying features of the experimental stimuli but rather comparing performance between natural groups with different background knowledge concerning the categories presented.

Experiment 1

Experiment 1 tested the categorization performance of 9- and 11-month-old infants participating in an OET that used cats vs. dogs as categorical contrast. Based on the work of Eimas and Quinn (1994), as well as Quinn and Eimas (1996), one would expect that category discrimination should be clearly present in both age groups. According to previous work using the OET, this seems unlikely, though. Mandler and McDonough (1998) reported that dogs were not discriminated neither from fish nor rabbits until 11 months of age, and Pauen (2002a) did not find any evidence for category discrimination of dogs from birds within the

first year of life. However, none of these studies did control for the amount of experiences that participants had with either category. Hence, we do not know whether the obtained results can be explained by differences in methods or by a-priori differences between the samples.

In Experiment 1, we test only infants without any background knowledge of cats or dogs. Based on existing findings obtained with the OET and on the assumption that previously acquired real-world knowledge is relevant for category discrimination this kind of task, we hypothesized that neither 9- nor 11-month-olds would show category discrimination.

Method

Participants

A total of $N = 40$ infants participated in Experiment 1. Twenty 9-month-olds (M age = 9;06, range = 9;00-9;23), and twenty 11-month-olds (M age = 11;06, range = 11;00-11;22). Infants' names were drawn from birth announcements. Their families were contacted via letters and phone calls. On the basis of parental reports, we only included those infants who had neither a cat nor a dog as pet, and who had no frequent contact with cats or dogs (e.g. in the neighbourhood, or by regular visits to friends and relatives). Six additional infants were originally tested but were excluded from further analyses due to fussiness ($N = 3$), experimental error ($N = 2$), or intervention by the parent ($N = 1$). All infants came from a white, middle-class socioeconomic background.

Material and Procedure

The material consisted of miniature toy replicas of five different dogs and five different cats (see Figure 1).



Figure 1. Material used in Experiment 1 (and Experiment 2).

The general procedure followed that of a classic object-examination task, used in earlier work (e.g. Mandler & McDonough, 1993, 1998; Pauen, 2002a, 2002b; Oakes, Madole, & Cohen, 1991). Infants were seated in a high chair in front of a table. After a short warm-up period, the experimenter put the first object within reaching distance of the child. The infant was allowed to freely explore the object for 20 seconds before it was taken away and replaced

by the next object. Infants received four different exemplars from one category for familiarization. The same series was presented twice (2 x 4 familiarization trials). During test infants received a new item from the familiar category (trial 9) and one item from the contrasting category (trial 10). Across subjects, each exemplar from a given category served equally often as test item. During the familiarization phase, a decrease in examination times from the first to the second presentation of the same exemplars was interpreted as a familiarization response. In test, an increase in examination time from the last familiarization exemplar to the new same-category test-exemplar suggests that infants recognize the perceptual novelty of the fifth exemplar of the familiar category, whereas an increase in examination from the first to the second test-exemplar indicates that infants recognize the change in category. (After all, both test-exemplars were perceptually new, but only the last belonged to a new category.) Half of the infants in each age group were familiarized with cats; the others were familiarized with dogs.

Coding

All sessions were videotaped and analyzed off-line by two independent coders (not involved in the process of data collection) for examination duration on each given trial. Examination duration was defined as the time, during which infants were concentrating on and inspecting the object (Oakes, Madole, & Cohen, 1991; Oakes & Tellinghuisen, 1994). It is assumed to reflect focused attention and increased cognitive involvement (Ruff, 1986), and has been shown to go along with a decrease in heart rate as compared to states of non-focused looking (Elsner, Pauen, & Jeschonek, 2006).

Results and Discussion

Mean inter-coder reliability for examination was $r = .97$. For each trial, the mean score of both coders provided the basis for further analyses.

Familiarization phase. To evaluate changes in the examination time during the familiarization phase, the average examination duration for the first half of the familiarization trials (phase A: trial 1 to trial 4) and for the repeated presentation of the same four objects (phase B: trial 5 to trial 8) were compared within a 2 x 2 repeated measures mixed model analysis of variance with age (9 months, 11 months) as between-subject factor and familiarization phase (phase A, phase B) as within-subject factor (see also Mandler & McDonough, 1993, 1998; Pauen, 2002a, 2002b). This analysis revealed a significant main effect for familiarization phase, $F(1, 38) = 23.25$; $p < .001$, η^2 (partial eta squared) = .38. Mean examination times decreased from $M = 5.12$ s ($SE = .45$) for the first half of the familiarization trials to $M = 3.19$ s ($SE = .42$) for the second half. There was also a significant main effect for age, $F(1, 38) = 7.84$, $p < .01$, $\eta^2 = .17$, with the 11-month-olds showing a longer mean examination time ($M = 5.16$ s, $SE = .51$) compared to the 9-month-olds ($M = 3.15$ s, $SE = .51$). The interaction between both factors failed to reach the level of significance.

Test phase. To investigate infants' performance during the test phase, mean examination times for the last object of the familiarization phase (trial 8), the novel object of the familiar

category (trial 9), and the novel-category object (trial 10) were entered in a 2 x 3 repeated measures mixed model analysis of variance with age (9 months, 11 months) as between-subject factor and trial (trial 8, trial 9, trial 10) as within-subject factor. This analysis only revealed a significant main effect for age group, $F(1, 38) = 11.73$; $p < .01$, $\eta^2 = .24$ with longer mean examination time for 11-month-olds ($M = 5.47s$, $SE = .60$) than for 9-month-olds ($M = 2.56s$, $SE = .60$). No other main effect or interaction reached the level of significance. Because we were specifically interested in potential developmental changes, additional planned comparisons were run to describe the pattern of familiarization and categorization for each age group separately (see also Mandler & McDonough, 1993). In both age groups there were significant decreases in infants' examination times during familiarization with $M_{\text{PhaseA}} = 3.97s$, ($SE = .52$) and $M_{\text{PhaseB}} = 2.33s$, ($SE = .58$) for the 9-month-olds and $M_{\text{PhaseA}} = 6.26s$, ($SE = .66$) and $M_{\text{PhaseB}} = 4.06s$, ($SE = .55$) for the 11-month-olds. Comparing the means of the last three trials (trial 8, trial 9, trial 10), none of the pair-wise comparisons reached level of significance, however. This means that examination duration did not change systematically from the last familiarization exemplar over the first test-item (new same-category exemplar) to the second test-item (out-of-category exemplar), neither in 9- nor in 11-month-olds. The corresponding mean values are presented in Figure 2.

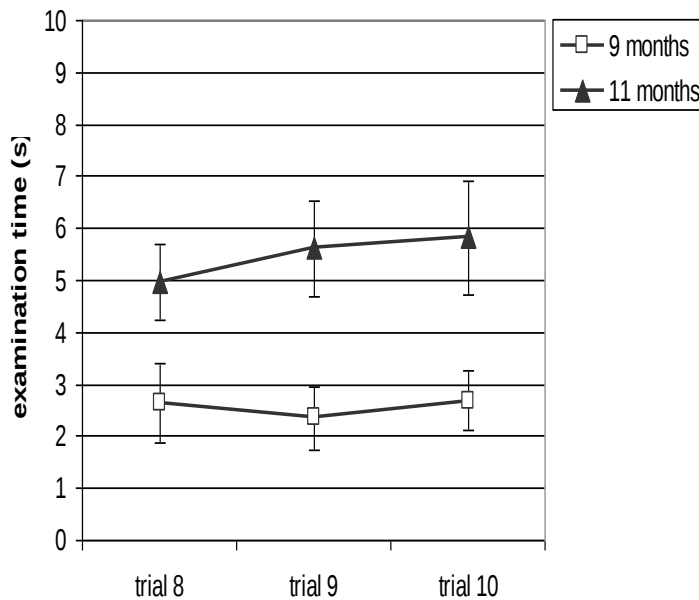


Figure 2. Experiment 1. Mean examination times for the three test trials (trial 8, 9, 10) for both age groups separately. Error bars represent $\pm 1 SE$.

Discussion

In contrast to previous studies using the VFT (Eimas & Quinn, 1994; Quinn & Eimas, 1996), but in accordance with previous studies using the OET and similar basic-level contrasts (Mandler & McDonough, 1998; Pauen, 2002a), Experiment 1 revealed that neither 9- nor 11-month-olds showed a categorization response in a cats-vs.-dogs task. During the

familiarization phase, examination times declined in both age-groups, suggesting that infants recognized the individual exemplars. When the same series of exemplars was presented for a second time, infants spent less time examining them. From the fact that no changes in mean examination time occurred during the test-phase, one may conclude that infants of the tested age-range still do not make more fine-grained distinctions within the animal domain – at least not between dogs and cats, and at least not if they are not yet familiar with these animal species. This finding provides indirect evidence supporting the idea that the OET measures different aspects of cognitive performance than the VFT.

Interestingly, 11-month-olds showed generally longer examination times than 9-month-olds. Considering the fact that information-processing speed increases with age, thus leading to shorter encoding times, one may wonder why it should take longer for older infants to process the given information. In an attempt to explain this finding, one may speculate that older infants are cognitively more engaged when examining the given toy-models, presumably because they already start activating information from long-term memory, but fail to succeed in categorizing the given material at test because they still have not acquired enough experiences with cats and dogs to clearly discriminate both species. If this interpretation of the reported data were correct, one could speculate that infants familiar with real-world cats and dogs may show even longer overall examination times, and/or they may succeed in distinguishing both species at test. Experiment 2 was conducted to test these hypotheses.

Experiment 2

Based on the assumption that categorization performances in an OET is not modulated by perceptual information about the experimental stimuli alone, but rather reflects the application of previously acquired knowledge about real-world exemplars, we expect 9- and/or 11-month-olds who are familiar with cats and dogs to show a categorization response in the same task that lead to a negative finding in same-aged infants who lacked corresponding background knowledge. If attempts to apply real-world experiences go along with more interest in the presented toy-models, overall examination times should be longer for infants participating in Experiment 2 than in Experiment 1. In addition, we are also interested in potential age-related changes in familiarization and categorization patterns.

Method

A total of $N = 40$ infants participated in Experiment 2; twenty 9-month-olds (M age = 9;10, range = 9;00-9;24), and twenty 11-month-olds (M age = 11;08, range = 11;00-11;20). Five additional infants were originally tested but were excluded from further analyses due to fussiness ($N = 3$), experimental error ($N = 1$), or intervention by the parent ($N = 1$). All infants came from a white, middle-class socioeconomic background. Contrary to Experiment 1, we only tested infants whose parents indicated that they either had a cat or a dog at home, and/or that infants often had contact to cats or dogs (for example in the neighbourhood or by regular visits to friends and relatives). Material, procedure, and coding were exactly the same as in

Experiment 1. Hence, the only difference between both experiments was the familiarity of the sample with cats and dogs.

Results and Discussion

Mean inter-coder reliability for examination was $r = .94$. For each trial, the mean score of both coders provided the basis for further analyses.

Familiarization phase. To evaluate changes in the examination time during the familiarization phase, the average examination duration for the first half of the familiarization trials (phase A) and for the repeated presentation of the same four objects (phase B) were compared within a 2×2 repeated measures mixed model analysis of variance with age (9 months, 11 months) as between-subject factor and familiarization phase (phase A, phase B) as within-subject factor. Again, this analysis revealed a significant main effect for familiarization phase, $F(1, 38) = 48.54$; $p < .001$, $\eta^2 = .38$. Mean examination times decreased from the first half of the familiarization trials $M = 7.18$ s ($SE = .33$) to the second half, $M = 5.63$ s ($SE = .32$). No other main effect or interaction reached the level of significance. At a descriptive level, one could see that mean examination duration during familiarization was much higher for infants who have frequent contact to real-world cats and dogs than for infants who lack this experience.

Test phase. The mean examination times for the last object of the familiarization phase (trial 8), the novel object of the familiar category (trial 9), and the novel-category object (trial 10) were entered in a 2×3 repeated measures mixed model analysis of variance with age (9 months, 11 months) as between-subject factor and trial (trial 8, trial 9, trial 10) as within-subject factor. This analysis revealed a significant main effect for trial, $F(2, 76) = 5.58$; $p < .01$, $\eta^2 = .13$. Examination times did not increase from the last familiarization trial to the first test-trial, but increased from the new item of the familiar category (trial 9) to the out-of-category item (trial 10), $t(39) = -1.97$, $p < .05$. The increase from the last item of the familiarization phase (trial 8) to the out-of-category item (trial 10), was also significant, $t(39) = -3.65$, $p < .001$. Corresponding mean values for the critical test trials were $M_{\text{trial8}} = 5.38$ s ($SE = .44$), $M_{\text{trial9}} = 6.35$ s ($SE = .65$), and $M_{\text{trial10}} = 7.80$ s ($SE = .63$).

Being interested in potential developmental changes, additional planned comparisons were run to describe the pattern of familiarization and categorization for each age group separately. In both age groups there were significant decreases in infants' examination times during familiarization with $M_{\text{PhaseA}} = 6.87$ s, ($SE = .45$) and $M_{\text{PhaseB}} = 5.24$ s, ($SE = .47$) for the 9-month-olds and $M_{\text{PhaseA}} = 7.50$ s, ($SE = .49$) and $M_{\text{PhaseB}} = 6.01$ s, ($SE = .44$) for the 11-month-olds. Comparing the means of the last three trials (trial 8, trial 9, trial 10), the analyses revealed that 9-month-olds showed only a marginally significant increase in examination times from trial 8 to trial 10, $t(19) = -1.53$, $p = .06$. Neither changes from trial 8 to trial 9 nor from trial 9 to trial 10 reached the level of significance. Among 11-month-olds, pairwise comparisons of mean examination duration during the test-phase (trial 8, trial 9, trial 10) revealed a marginally significant increase from trial 8 to trial 9, $t(19) = -1.64$, $p = .058$, a significant increase from trial 9 to trial 10, $t(19) = -1.83$, $p < .05$, as well as a significant increase from trial 8 to trial 10, $t(19) = -4.08$, $p < .001$. Apparently, only the older infants recognized the change in category between trial 9 (new exemplar familiar category) and trial 10 (out-off-category exemplar). Corresponding mean values are shown in Figure 3.

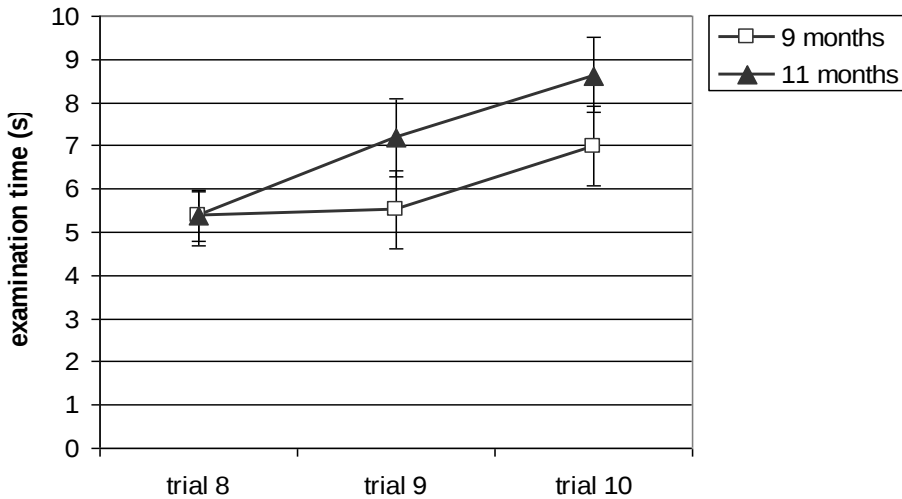


Figure 3. Experiment 2. Mean examination times for the three test trials (trial 8, 9, 10) for both age groups separately. Error bars represent ± 1 SE.

In sum, we found that infants who had daily experience with cats or dogs showed a familiarization as well as a categorization response. Their categorization pattern revealed that the new member of the familiarized category was treated as equivalent to the exemplars presented during familiarization phase, whereas the out-of category item was treated as new. In both age groups, it was examined significantly longer than the last familiarization item. Even though the overall analysis did not show an impact of the factor *age* on infants' examination behaviour during the test phase, a closer look within the separate age groups indicates interesting changes between 9- and 11 months of age. Nine-month-old infants showed only a significant increase between trial 8 and trial 10. Following Mandler and McDonough (1993), this reflects an ambiguous categorization pattern because not both test trials were treated as new. On a descriptive level we found an increase in examination time between trial 9 and trial 10, but not between trials 8 and 9 (see Figure 3). This means that 9-month-old infants treated the new item from the familiar category as equivalent to the exemplars seen before, but responded with increased interest to the out-of category item. In contrast, the pattern shown by 11-month-old infants, with trial 8 < trial 9, and trial 9 < trial 10, indicates that the new member of the familiar category was recognized as new, but the exemplar from the contrasting category was treated as clearly distinct, presumably because infants recognized the change in category membership. Mandler and McDonough (1993) call this pattern *advanced categorization* because infants discriminate the new exemplar from the familiarized category from the previous exemplars as well as from the out-of category item.

General Discussion

Two related experiments investigated the role of previously acquired real-world knowledge for categorization performance in an Object Examination Task (OET). Experiment 1 revealed that 9- and 11-month-old infants who did not have any daily experiences with cats or dogs failed to differentiate between these two categories. In contrast,

Experiment 2 indicated that infants who did have corresponding experience clearly distinguished between these two basic-level categories, with older infants showing a more advanced pattern of categorization than the younger group.

The lack of a categorization response in a basic-level OET contrasting different mammal species is in accordance with existing literature. Basic-level distinctions typically start emerging towards the end of the first year of life while distinctions between global-level categories (e.g., animals and furniture or vehicles) are found much earlier (Mandler & McDonough, 1993, 1998; Pauen, 2002a, 2002b). One interpretation of this set of findings is that 3-D models which can be explored visually as well as manually activate previously acquired knowledge about behavioural properties of real-world objects. What type of knowledge might that be? Knowledge about the movement behaviour is assumed to develop early in life. More specifically, young infants are specifically interested in the causation and the path of movement, which clearly distinguish animates from inanimate (e.g., Gelman, Durgin, & Kaufman, 1995; Legerstee, 1994; Mandler, 1992a, 1992b, 2000a, 2000b; Molina, Spelke, & King, 1996; Poulin-Dubois & Shultz, 1988; Premack, 1990; Premack & Premack, 1995; Spelke, Phillips, & Woodward, 1995). Infants are sensitive to this type of distinction at 7 months of age (Pauen & Träuble, 2002; Träuble, Pauen, Schott & Charalampidu, 2006). Due to the lack of experience with various animal species, it may take some more months until infants are able to make more fine-grained distinctions within these two global domains, hence leading to the finding of a global-to-basic level shift during the second half of the first year of life. Consistent with this interpretation, we found that older infants participating in Experiment 1 were cognitively more involved in the given basic-level task than the younger age-group (as indicated by longer overall examination times), but that both age-groups still failed to distinguish cats from dogs if they only had occasional contact with exemplars from these animal-kinds.

Among those who were highly familiar with cats and dogs (Experiment 2), category discrimination was likely to occur. A comparison of the categorization patterns of the 9- and the 11-month-olds in Experiment 2 revealed that younger infants still showed the pattern of *ambiguous categorization* while older infants showed the pattern of *advanced categorization*. Apparently, mere exposure to real-world exemplars is not sufficient to categorize cats and dogs in an OET. If that were the case, performance at test should have been the same for age-groups. Rather, age made a difference in terms of how strong performance was influenced by previously acquired knowledge: 11-month-old infants participating in Experiment 2 also showed a tendency to examine the objects presented during familiarization for a longer time than 9-month-olds, presumably because the older they were more strongly involved in processes of memory activation. Hence, one could speculate that infants' ability to encode and to memorize differentiated experiences with real-world exemplars, and/or to activate basic-level knowledge in an OET shows developmental progress between 9 and 11 months of age.

In sum, the reported findings strongly suggest that the activation of real-world knowledge plays a crucial role for explaining OET-performance, while leaving open the question what type of knowledge infants applied. Participants of Experiment 2 had experience with only one specific exemplar of a cat or a dog. Hence, it is all but self-evident that they have formed a "perceptual category" based on the experience of multiple items. Of course, the experience with one specific exemplar might have increased infants' sensitivity to features of cats or dogs in general, thus leading infants to pay more attention to such features when encountering

similar exemplars outside their home. Alternatively, previous experience with one specific exemplar might have lead to an increase in interest for toy-models with similar appearance, thus helping the infant to form a category on-line during the experimental session. The present data can not decide between these two alternatives.

One addition question still remaining unanswered is whether it is really necessary to have previous experience with real-world exemplars in order to be successful in the OET. Maybe performance would even be better if infants were pre-exposed to toy-models of dogs and cats rather than a real cat or dog? This possibility could further be explored by allowing infants to play with either one or multiple toy replica of a cats and/or dogs for several weeks. If they show similar performance as those participating in Experiment 2, this would weaken the argument that infants of the tested age-range rely on real-world experience when categorizing toy-models in a laboratory task. If they show a lack of categorization, the same argument would be strengthened, however.

The present study was the first to demonstrate that previously made experiences with real-world-exemplars can influence infants' categorization behaviour in an object-examination task. Additional investigations need to clarify what kind of experience is necessary to show this effect.

REFERENCES

- Behl-Chadha, G. (1996). Basic-level and superordinate-like categorical representations in early infancy. *Cognition*, 60, 105-141.
- Eimas, P., & Quinn, P. (1994). Studies on the formation of perceptually based basic level categories in young infants. *Child Development*, 65, 903-917.
- Eimas, P. D., Quinn, P. C., & Cowan, P. (1994). Development of exclusivity in perceptually based categories of young infants. *Journal of Experimental Child Psychology*, 58, 418-431.
- Elsner, B., Pauen, S., & Jeschonek, S. (2006). Physiological and behavioral parameters of infants' categorization: Heart rate and duration of examining across trials. *Developmental Science*, 9, 551-556.
- Gelman R. (1990). First principles organize attention to and learning about relevant data: Number and the animate-inanimate distinction as examples. *Cognitive Science*, 14, 79-106.
- Gelman, R., Durgin, F., & Kaufman, L. (1995). Distinguishing between animates and inanimates: Not by motion alone. In D. Sperber, D. Premack, & A. J. Premack, (Eds.), *Causal Cognition- A Multidisciplinary Debate*, (pp. 150-184). Oxford: Clarendon Press.
- Legerstee, M. (1994). Patterns of 4-month-old infant responses to hidden silent and sounding people and objects. *Early Development and Parenting*, 3, 71-80.
- Mandler, J. (1992a). How to built a baby: II. Conceptual primitives. *Psychological Review*, 99, 587-604.
- Mandler, J. (1992b). The Foundations of Conceptual Thought in Infancy. *Cognitive Development*, 7, 273-285.

-
- Mandler, J. (2000a). What Global-Before-Basic Trend? Commentary on Perceptually Based Approaches to Early Categorization. *Journal of the International Society on Infant Studies*, 1, 99-110.
- Mandler, J. (2000b). Perceptual and Conceptual Processes in Infancy. *Journal of Cognition and Development*, 1, 3-36.
- Mandler, J. (2004). *The Foundations of Mind: Origins of Conceptual Thought*. Oxford: Oxford University Press.
- Mandler, J., & McDonough, L. (1993). Concept formation in infancy. *Cognitive Development*, 8, 291-317.
- Mandler, J., & McDonough, L. (1998). On Developing a Knowledge Base in Infancy. *Developmental Psychology*, 34, 1274-1288.
- Mareschal, D., & French, R. (2000). Mechanisms of Categorization in Infancy. *Journal of the International Society on Infant Studies*, 1, 59-76.
- Molina, M., Spelke, E. S., & King, D. (1996, April). The animate-inanimate distinction in infancy: Sensitivity to distinctions between social interactions and object manipulations. Poster session presented at the International Conference on Infant Studies, Providence, RI.
- Oakes, L. M., & Tellinghuisen, D. J. (1994). Examining in infancy: Does it reflect active processing? *Developmental Psychology*, 30, 748-756.
- Oakes, L., Madole, K., & Cohen, L. (1991). Infants' object examining: Habituation and categorization. *Cognitive Development*, 6, 377-392.
- Pauen, S. (2000). Early Differentiation within the Animate Domain: Are Humans Something Special? *Journal of Experimental Child Psychology*, 75, 134-151.
- Pauen, S. (2002a). The global-to-basic-level shift in preverbal infants. First evidence from a longitudinal study. *International Journal of Behavioural Development*, 26, 492-499.
- Pauen, S. (2002b). Evidence for knowledge-based category discrimination in infancy. *Child Development*, 73, 1016-1033.
- Pauen, S., & Träuble, B. (2002). Causal attribution of animate motion in 7 months olds. Paper presented at the 13th International Conference on Infant Studies ICIS, Toronto, Can.
- Poulin-Dubois, D., & Shultz, T. R. (1988). The development of understanding of human behaviour: From agency to intentionality. In: J. W. Astington, P. L. Harris, & D. R. Olson (Eds.), *Developing theories of mind* (pp. 109-125). Cambridge: Cambridge University Press.
- Premack, D. (1990). The infant's theory of self-propelled objects. *Cognition*, 36, 1-16.
- Premack, D., & Premack, A. J. (1995). Intention as psychological cause. In: D. Sperber, D. Premack, & A. J. Premack, (Eds.), *Causal Cognition - A Multidisciplinary Debate*. Oxford: Clarendon Press.
- Quinn, P., & Eimas, P. (1996). Perceptual cues that permit categorical differentiation of animal species by infants. *Journal of Experimental Child Psychology*, 63, 189-211.
- Quinn, P., Eimas, P., & Rosenkrantz, S. (1993). Evidence for representations of perceptual similar natural categories by 3-month-old and 4-month-old infants. *Perception*, 22, 463-475.
- Quinn, P., & Johnson, M. (2000). Global-Before-Basic Object Categorization in Connectionist Networks and 2-Month-Old Infants. *Journal of the International Society on Infant Studies*, 1, 31-46.

- Ruff, H. (1986). Components of attention during infants' manipulative exploration. *Child Development*, 57, 105-114.
- Spelke, E. S., Philips, A., & Woodward, A. L. (1995). Infants' knowledge of object motion and human action. In: D. Sperber, D. Premack, & A. J. Premack, (Eds.), *Causal Cognition - A Multidisciplinary Debate*, (pp. 44-78). Oxford: Clarendon Press.
- Träuble, B., & Pauen, S. (2007). The role of functional information for infant categorization. *Cognition*, 105, 362-379.
- Träuble, B., Pauen, S., Schott, S., & Charalampidu, A. (2006). Do 7-month-old infants pay attention to causality in ambiguous dynamic events? Poster presented at the 15th International Conference on Infant Studies, ICIS, Kyoto, Japan.
- Younger, B., & Fearing, D. (2000). A Global-to-Basic Trend in Early Categorization: Evidence From a Dual-Category Habituation Task. *Journal of the International Society on Infant Studies*, 1, 47 –58.

Author Note: This work has been funded by the German Research foundation. We are grateful to the infants and parents who participated in this research. Thanks to our student research assistants for running the experiments and scoring the video tapes.

Chapter 19

PERIPHERAL RESPONSES ELICITED BY MOTOR IMAGERY: A WINDOW ON CENTRAL AND PERIPHERAL NERVOUS SYSTEM RELATIONSHIPS THROUGH MOTOR COMMANDS INHIBITION

C. Collet and A. Guillot*

¹University of Lyon, Claude Bernard University, Lyon, France

ABSTRACT

The aim of this paper was to examine the way in which motor commands addressed to the somatic and autonomic effectors are inhibited during Motor Imagery (MI). Three experiments are described, each referring to specific motor requirements. The first requested the participants to lift a weighted dumbbell with their preferential hand (flexion of the forearm), while seating in a chair. In the second task, the participants were asked to perform 3 consecutive vertical jumps on a force plate, while the third was a coincidence anticipation task requiring intercepting a table-tennis ball thrown by a robot, with the inner side of the hand. All were performed under actual vs. mental practice. In the first experiment, a subliminal muscular activity was recorded during MI, which was specific to the type of muscle contraction. In the second experiment, MI was shown to reduce postural sway amplitude in the standing position on both the anterior-posterior and the lateral axes compared to the control condition (standing motionless on the force plate). In the third experiment, the autonomic responses recorded during MI showed the same pattern that those recorded during actual movement. While performing MI, the 3 motor commands were thus shown to be affected differentially with reference to somatic and autonomic inhibition.

Experiment 1 provided evidence that direct voluntary commands are not fully inhibited during MI. Although this process remained not solved, it is supposed at organising peripheral effectors during the preparation phase, as for the actual execution of the movement. The incomplete inhibition of motor commands was confirmed by the second experiment as postural adjustments were not inhibited. Accordingly, MI may thus

* CRIS-EA 647 – Laboratory of Mental processes and Motor performance, 27-29 Boulevard du 11 Novembre 1918, 69622 Villeurbanne Cedex, France. christian.collet@univ-lyon1.fr – aymeric.guillot@univ-lyon1.fr

have a more limited effect on automatic sensori-motor processes usually associated to voluntary motor commands. This was confirmed in the third experiment in which autonomic nervous system regulations were preserved during MI.

These findings should be used in MI program (in sport training or clinical rehabilitation), as incomplete inhibition may give feedback information to the central nervous systems. Further research should nevertheless investigate the processes of somatic motor commands inhibition.

Keywords: Motor imagery – Voluntary movement – Motor commands inhibition – Electromyography – Autonomic nervous system activity – Postural adjustments

INTRODUCTION

Motor Imagery (MI) is the mental representation of a given movement without any concomitant body action. MI could be performed through several modalities, each linked to a sensorial system. With reference to motor action, the most commonly used are the visual imagery (VI) which requires self-visualization of movement, whereas the kinaesthetic imagery (KI) requires to “perceiving” the movement through muscle contraction intensity and joint amplitude. Since similar mechanisms underlying movement preparation and execution are shared with motor imagery (Decety, 1996), it has been shown that the effects of MI may improve motor task performance (Roure et al., 1999; Mulder et al., 2004; Guillot & Collet, 2008). MI involves several cerebral operations (mental evocation and representation), which do not elicit any behavior and, consequently, cannot be observed although cerebral scanning with TEP or fMRI evidences cerebral changes through blood flow variations. If mental operations of motor planning and programming are actually performed during MI, motor commands must be inhibited to prevent any movement. The level at which the motor command is stopped has never been clearly identified. It may be supposed that both the motor areas and the motor tracks are involved in the process of inhibiting efferent information addressed to muscles (Bonnet et al., 1997).

Voluntary motor commands originate from cerebral cortices, particularly from the frontal and parietal areas which are closely linked with subcortical structures, i.e. the basal ganglia and the lateral cerebellum. In addition, automated postural adjustments are integrated to motor commands to anticipate any postural disturbance elicited by the movement execution itself.

Finally, a part of the motor program, which is often overlooked, is related to the autonomic nervous activity that provides homeostatic regulations by mobilizing the resources of the organism in response to energetic demands of the internal milieu. By providing information about the activity of the sympathetic branch, electrodermal data, clearly offer a window on cortical motor areas from which information is originated. These pathways are known to elicit increased activation, at the level of peripheral effectors, including the skin. When sweat glands are activated, a concomitant electrodermal response is elicited. Thus, cognitive operations of the central nervous system, such as MI, are paralleled by peripheral electrodermal system (for review, see Guillot & Collet, 2005).

Three experimental designs will be presented in this study, each with specific motor requirements. The first task required the participants to lift a weighted dumbbell with their

preferential hand (flexion of the forearm), while seating in a chair. The second task was performed on a force plate on which the participants had to perform a series of 3 consecutive vertical jumps. The third task was a Go/No-Go task, asking the participants to intercept table-tennis balls thrown by a robot, with the inner side of their hand and by extending their arm.

All these tasks were performed under two conditions, i.e. actual vs. mental practice. Taking into account the movement requirements, the aim of this study was to examine the ways in which the motor commands addressed to somatic and autonomic effectors were inhibited during MI.

First Experiment

Materials and Methods

The first experiment required the participants to lift a weight while seated, both physically and mentally. Thirty right-handed sport students took part in this experiment. During a preliminary session, held seven days before the experiment, all the participants were asked to perform 2 tests: an incremental test to determine their best mark (1RM) of a concentric contraction with a weighted dumbbell.

A strain gauge force transducer was also used to determine their maximum isometric strength. After a specific warm-up, the experimental procedure required the participants to seat comfortably in an experimental chair and to gradually lift dumbbells of an increasing weight. To avoid any compensatory movements, participants were attached to the chair. The experimenter then placed the EMG electrodes on the active arm.

Surface EMG signals were simultaneously recorded with the Flex-comp Infinity system (Thought technology, Montreal, Canada), from the long head of the biceps brachii (LBB), the short head of the biceps brachii (SBB), the brachioradialis (BR), the triceps brachii (TB), the flexor carpi ulnaris (FCU), the flexor carpi radialis (FCR), the anterior deltoid (DEL), the superior trapezius (TRA), and the major pectoralis (PEC) muscles.

A goniometric system was also attached to the active arm and forearm, to control the initial position and check that the initial elbow angle (90°) remained constant during MI. The participants were then asked to actually lift or to imagine lifting the weighted dumbbell. The four conditions were *i)* heavy concentric contraction (80% of 1RM), *ii)* light concentric contraction (50% of 1RM), *iii)* isometric contraction (95% of the maximal isometric strength) with the strain gauge force transducer, and *iv)* eccentric contraction (120% of 1RM). Four actual and 4 imagined conditions were counterbalanced for each contraction type. During their actual performance, the participants were asked to lift the dumbbell as fast as possible (concentric contractions), to slow it as much as possible (eccentric contraction), or to hold an isometric contraction during a 5s-period (arm-forearm angle=90°).

During MI, they were instructed to imagine the movement as if they were actually performing it, using a combination of both internal visual and kinesthetic imagery. Upon mental initiation of the first body movement and at the end of the sequence, athletes pressed a button with their non-dominant hand, to start and stop the timer. The experimental design is summarized in Figure 1.



Figure 1. The first experiment requested the participants to lift a dumbbell with their preferential arm (as shown by the picture on the left). Several experimental conditions were selected to make the muscles controlling the flexion movement working under different contraction modalities (isometric, heavy concentric, light concentric and eccentric). Those 4 types of contractions were paralleled by similar motor imagery activity (right picture).

RESULTS

All measurements monitored from the 9 muscles were considered under the MI condition. The first step was to test the interaction between movement condition and the type of muscle contraction. None of the P-values reached a significant level, although some revealed a marginally significant P-value. Consequently, the effect of each condition was investigated. Statistical analysis showed a significant difference between the MI and rest conditions, the EMG muscle activity being systematically higher during MI than during the rest period. These differences were observed in all muscles. A significant effect of the contraction type was found in the anterior deltoid, the brachioradialis, the flexor carpi ulnaris, and the flexor carpi radialis. Interestingly, the weakest muscle activity was found during the eccentric MI. EMG data recorded during MI also provided a strong difference between the two concentric conditions, powerful concentric contraction eliciting higher muscular activity than weak concentric contraction, just as seen during the actual performance. Finally, no clear difference emerged from the comparison of powerful concentric and isometric contractions. These results are summarized in Figure 2 and 3.

DISCUSSION

The data provided by the EMG analysis showed a clear difference between the rest period and the MI condition whatever the gender, the muscles and the type of contraction. A subliminal muscular activity was thus recorded during MI, which was also specific to the type of muscle contraction. These results may highlight the incomplete inhibition of motor commands during MI. We also observed an effect of the weight being mentally lifted under

the concentric condition, the heavy dumbbell eliciting a higher EMG activity than when the weak dumbbell is lifted mentally. Bakker et al. (1996) and Boschker (2001) had found that

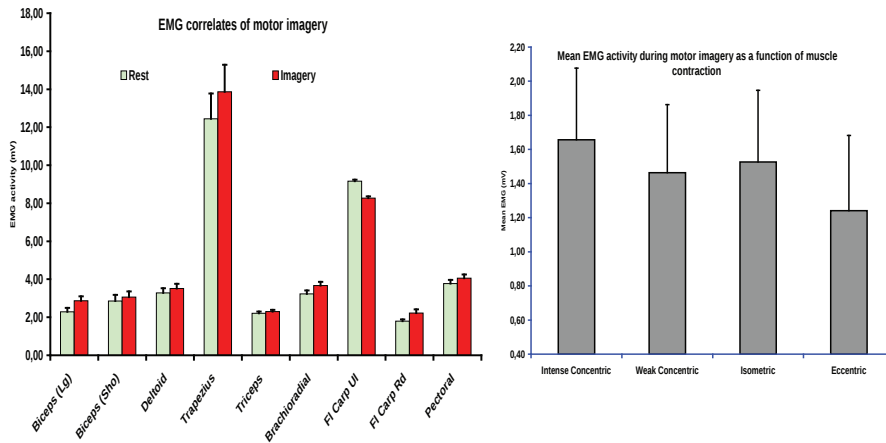


Figure 2. Muscular activity during motor imagery, although subliminal, was higher than that recorded during the control condition (left figure). Furthermore, EMG activity during motor imagery was shown as matching this observed during actual movement, the highest values being obtained during the strong concentric condition whereas the lowest was observed during the eccentric contraction (right figure).

lifting a 9 kg dumbbell mentally resulted in a larger EMG activity than for lifting 4 kg 1/2. In the present study, the MI of a heavy concentric contraction (80% of 1RM) resulted in a greater pattern of EMG activity than during the MI of a light concentric condition (50% of 1RM). The intensity of the imagined contraction is thus paralleled by the magnitude of the subliminal EMG activity, showing a close link between the central nervous system and the periphery during MI (Guillot et al., 2007). Jeannerod (1994) and Bonnet et al. (1997) attributed the changes in the EMG activity during MI to an incomplete inhibition of the motor command. This hypothesis is emphasized by differential muscle activity associated with the contraction type: the EMG activity was larger during the heavy concentric contraction than during the eccentric condition, this latter eliciting the weakest EMG activity among the 4 contraction types. Interestingly, these results reinforce the previous findings showing that actual eccentric contractions may elicit the weakest EMG activity, as compared to those observed during concentric and isometric contractions (Fang et al., 2001; McHugh et al., 2002). These results also confirm those by Komi et al. (2000) and Linnamo et al. (2006) who reported that the pattern of activity during imagined contractions was greater during concentric than during isometric conditions. As observed in our experiment, they also recorded a pattern of EMG activity in all muscles involved in the physical flexion of the forearm, i.e. the agonist muscles, but also the antagonists, synergists and muscles with a fixation function. This observation clearly shows that MI may recruit the same movement pattern as the actual motor command would do, although at a level of subliminal intensity, hence involving the same neural substrate. Thus, the EMG activity recorded during MI mirrored that observed during actual execution. Furthermore, this was not a tonic non-specific activity as the design of EMG distinguished among the different types of contraction in the same extent as actual execution would have done. However, two questions remain worthy to be asked: *i)* the usefulness of this specific residual motor command and *ii)* the neural process of partial inhibition of the motor command. As far as the first question is considered, one of the most plausible outcomes is that the sensory afferent information provided to the central

nervous system should serve as feedback in the hypothesis of a forthcoming actual movement. Secondly, the cerebellum is known as being involved in the inhibition of movement execution during MI (Lotze et al., 1999).

To summarize, the present results give evidence that specific EMG patterns were recorded during MI in all muscles interested in the movement, as a function of the force to be developed and of the contraction type. This interrelation may be summarized in Figure 3.

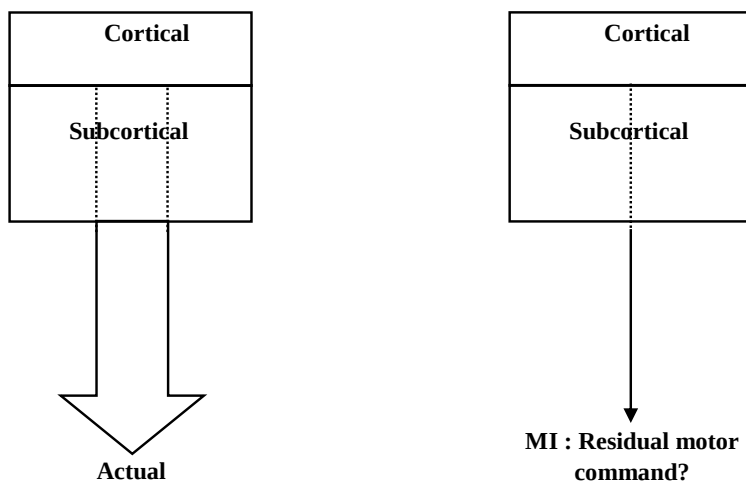


Figure 3. A pragmatic representation of what may occur during the mental representation of a movement, by comparison to what is actually performed by the central nervous system. The voluntary motor command, while being inhibited as no movement could be observed during motor imagery, is nevertheless thought as being partially inhibited, as a residual, specific and subliminal EMG activity may be recorded at the muscle level.

Second Experiment

Materials and Methods

The second experiment was devised to evaluate the effect of MI on postural adjustments. Postural stability was measured *i)* while the participants stood barefoot and motionless on a force plate, and *ii)* while they imagined a series of 3 consecutive vertical jumps, by using both visual (VI) and kinaesthetic imagery (KI), alternately. Remaining motionless on the force plate during the same duration was considered the control task, as showed by Figure 4.

Results

By comparison to the control condition, the MI task was shown to reduce both postural sway amplitude and path length in the standing position on the anterior-posterior and the lateral axes. Moreover, the participants were found to be more stable during VI than during KI, as shown by Figure 5. The current results showed that the postural adjustments were not inhibited during MI, whereas the movement commands were. The hypothesis that cognitive tasks enhanced standing postural stability is also reinforced. Results provided further

evidence that MI duration was longer than that recorded during the actual performance. This overestimation was greater during KI than during VI.



Figure 4. The left figure represents the control condition during which the participants were requested to stand motionless during a time-interval equivalent to that of the motor imagery of three consecutive vertical jumps. The left figure may also represent a participant during the mental representation of the task, i.e. imagining the 3 vertical jumps. The picture on the right illustrates a participant ready to perform the task.

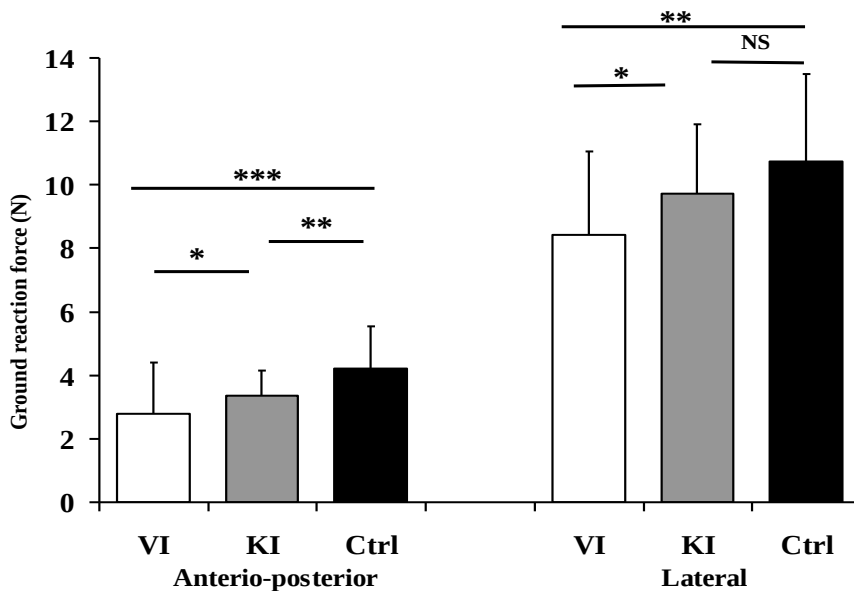


Figure 5. Comparison of postural sway extracted from the ground reaction force using the double integration method. The motor imagery sequences clearly show that comparing to the control condition, the postural body sway decreased both along the anterior-posterior and the lateral axis. This reduction is clearly due to the motor imagery activity through 2 main processes: i) attentional resources consuming and ii) increased stiffness due to postural motor commands addressed to muscles from the brainstem.

Discussion

As far as MI effects on postural control are considered, we observed a reduction of both postural sway amplitude and path length on the anterior-posterior and the lateral axis. Several types of cognitive operations have previously been shown to improve postural control (e.g. Marsh et al., 2000; Redfern et al., 2001; Teasdale et al., 1993). Due to the nature of the secondary task (e.g. visual stimulation vs. verbal tasks), dual-task effects on gait remained difficult to compare one to another. However, our results are in accordance with those reported by Riley et al. (2003), especially by avoiding the factors known as disturbing the posture independently of cognitive processes. Interestingly, these authors had highlighted a decrease in sway during a digit rehearsal task, and thus identified a significant relationship between postural regulation and attentional demands. This is consistent with the emerging view that postural control is not only under automated, non-conscious processes. As MI consumed attentional resources, postural regulations could have been made by automatic processes (Woollacott & Shumway-Cook, 2002; Ehrenfield et al., 2003). Releasing postural control from attentional focus is however based on the assumption that attention is directed toward a concurrent task, to make the postural control working in a more automatic and probably more efficient way. Such a reduction of the postural sway may be related to the tensing of postural muscles elicited by MI, thus resulting in increased stiffness. In the particular case of the vertical jump, the subliminal muscle activity hypothesis has to be demonstrated at the level of postural muscles. MI may be hypothesized as being the origin of the increased stiffness, as experiment 1 clearly showed that MI elicited subliminal and muscle-related responses. This tonic activity may therefore be considered an influencing factor in increasing the postural stability, especially because the actual movement requires anticipated postural regulation. This hypothesis, however, needs some experimental investigation dealing with movement involving both tonic (postural) and phasic (movement) muscle activity. Consequently, and as the sway was reduced under the MI condition, when compared to the control condition, postural adjustments were not inhibited during MI. Automatic sensory-motor regulations were thus preserved, despite the motor activity was inhibited. Postural regulation could be explained by the particular requirements of the movement. In other words, postural stability may be improved if the secondary task is correlated with a postural regulation (Le Pellec & Maton, 2000). This purpose is attested by Aruin et al. (2003), who reported that anticipated postural adjustments amplitude was lower during a task in which postural muscles were not involved, by comparison to motor tasks requiring strong postural regulations. To summarize, the decrease in postural sway may be explained by two main factors *i*) attention which is mainly focused on the mental task, thus allowing a more automatic and undoubtedly more effective postural control, and *ii*) a subliminal muscle activity may have occurred during MI, as previously considered by experiment 1. Thus, in a motor task like the vertical jump, MI brings arguments in favour of non-inhibited postural adjustments, as represented in Figure 5.

The functional role of uninhibited postural motor commands should now be questioned. It seems obvious that such a process may serve motor preparation just as the specific subliminal muscle activity evidenced during experiment 1. The role of anticipated postural adjustments is well-known since several years in the field of motor control (Lee, 1980). These are integrated to the phasic motor command that elicits action and are aimed to serve movement execution efficiency.

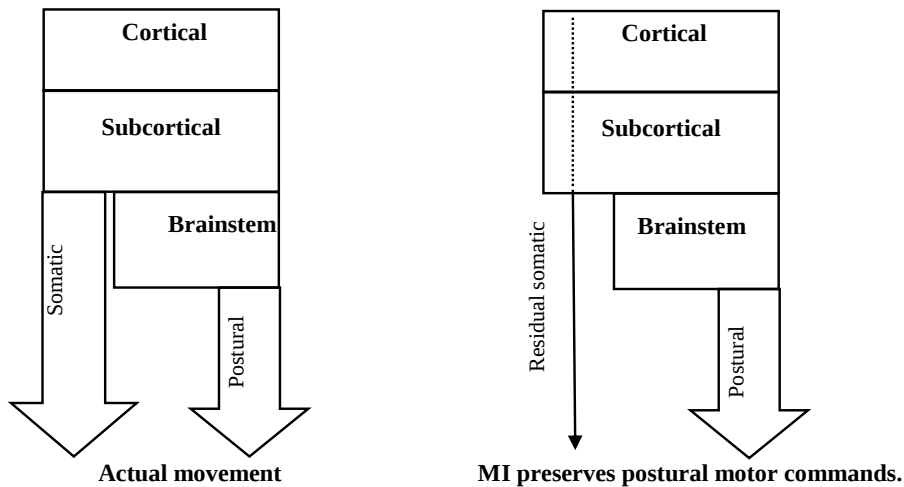


Figure 6. Schematic representation of a somatic motor command actually addressed to muscles with an integrated postural commands controlled by the brainstem (on the left). As the phasic motor command is inhibited partially during motor imagery, the postural command remains effective during the mental representation of the movement (on the right).

Third Experiment

Materials and Methods

Experiments 1 and 2 have both shown a partial inhibition of the somatic motor commands while holding a mental representation of a movement. The aim of the third experiment was to investigate whether the autonomic nervous system activity during MI was preserved, and to compare the autonomic responses observed during both actual execution and MI. Using a motor task requiring motor anticipation, 16 subjects were requested to both physically and mentally intercept green table-tennis balls thrown by a robot, with the inner side of their hand and by extending their arm (Figure 6).

The participants were confronted to 5 series of 10 balls. In order to preserve a high level of motivation, the experimental constraints (distance from the robot, speed of throwing) were divided in a way eliciting no more than 80% success, and no less than 20% failure. Subjects were warned before each trial that projections would occur within intervals of 5s after the warning signal.

To prevent any prediction of ball-throwing, various time delays between the warning signal preparation and the projection were used. Thus, the participants should process actual visual information and then program the adequate motor response. Autonomic nervous system activity was recorded continuously through skin resistance and instantaneous heart rate, thus being considered dependent variables. Each trial was separated from the next by a rest-period which was never less than 40s to make the physiological variables recovering the basal level (pre-stimulation values). As the task was unimanual, the autonomic responses were recorded from the non-dominant hand during either of the two conditions, actual or imagined. Autonomic responses were quantified by measuring amplitude and duration.

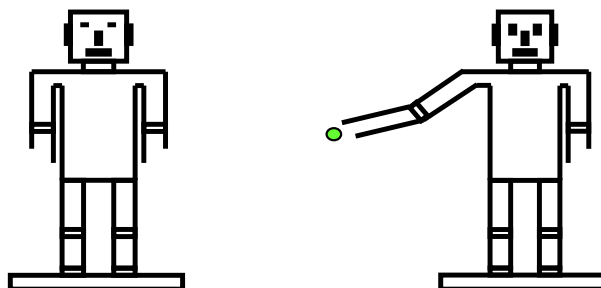


Figure 6. Schematic representation of the experimental design in which the participants had to intercept a table tennis ball thrown by a robot at various time intervals (to prevent habituation). From a motionless standing position (left figure), the participants had to perform interception with a forearm and arm extension movement. Physiological data i.e. electrodermal and cardiac activities were recorded through sensors placed on the non dominant hand (skin resistance sensors on the second and third phalanx) and in pre-cordial position using a thoracic auto-adhesive belt (instantaneous heart rate).

Results

Autonomic responses recorded during both movement execution and MI showed the same pattern. Nevertheless, responses recorded under the MI condition were generally weaker and shorter than those observed during actual execution, although the difference never reached the significant threshold. Thus, no difference emerged between the actual execution and the MI conditions. Interestingly, the successful trials resulted in longer autonomic response duration in action execution than failed trials. Figure 7 summarizes the main findings of experiment 3.

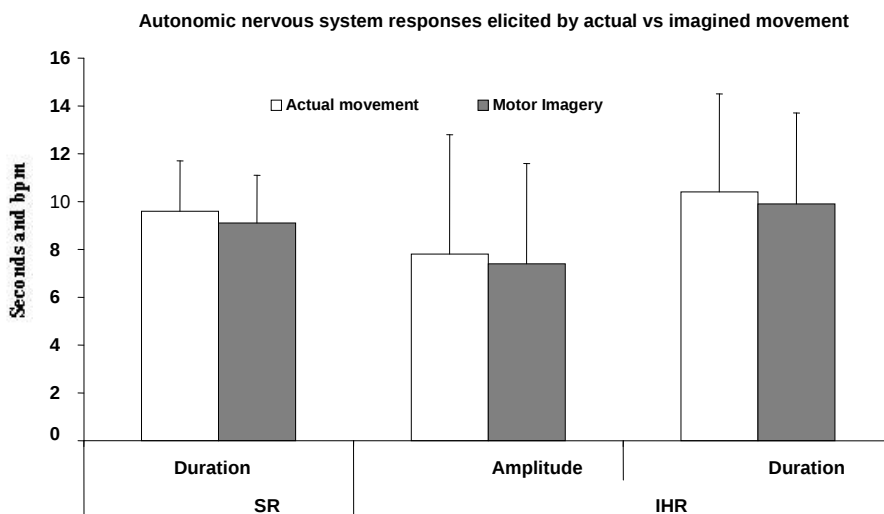


Figure 7. Actual execution and motor imagery showed the same autonomic response patterns. Thus, autonomic adaptations that accompany motor execution are not inhibited during the representation of movement. SR: Skin resistance – IHR: Instantaneous Heart Rate – bpm: beats per minute.* Skin resistance amplitude was not processed as this index is dependent upon the initial value. Thus, the comparison of SR responses was made on the basis of the response duration only.

Discussion

The main outcome from experiment 3 is that autonomic nervous system activity associated with somatic motor commands was fully preserved during MI *per se*. The autonomic function is designed to ensure homeostatic regulation and to supply additional needs of energy to peripheral effectors. On the basis of electrodermal and cardiac responses, we observed that the sympathetic branch activity remained comparable to that triggered for actual execution, even if the movement was not actually performed. The rationale for such an observation may probably originate from the need of the organism to be ready to act. Autonomic regulation is closely correlated and specifically adapted to movement requirement. To perform a voluntary movement, central operations (planning and programming) are paralleled by autonomic nervous system processes that provide energy resources to peripheral effectors: ANS responses or somatic muscles activation anticipate behaviour during the preparation phase, thus representing non-conscious physiological mechanisms of central mental processes (Collet et al., 1999; Sequeira and Ba M'hamed, 1999). After the “intention to move” operation, subjects have to process the preparation phase even if what was intended to do is not currently performed. This may explain why autonomic responses were recorded during MI as the autonomic function must anticipate the need for energy. Present results confirm that movement is planned and programmed both at a somatic and a visceral level. This co-programmation is supposed to elicit muscular contractions (although not sufficient to provide movement), as well as autonomic responses. It is now well-known that the autonomic nervous system is rapidly activated to respond to demands of the internal milieu (Wallin & Fagius, 1986). Kummer (1992) and Porges (1995) have provided evidence that these modifications are structurally and functionally task-related. Thus, the present results confirm that the autonomic nervous system is not purely a non-cognitive and automatic part of brain function (Hugdahl, 1996), but reflects behavioural outputs (Guillot & Collet, 2005). Specifically, the autonomic nervous system provides resources to peripheral effectors during motor commands preparation, whether effective or not, and offers a window on central nervous system functioning (Figure 8).

GENERAL DISCUSSION AND CONCLUSION

Two different mechanisms are involved in the inhibition of a voluntary action. The first is related to central programming processes whereas the second is responsible for central motor command transmission from central structures to peripheral effectors (De Jong et al. 1990). As early hypothesized by Jeannerod (1994), the neural commands for muscular contractions may be blocked at some level of the motor system by active inhibitory mechanisms. This purpose was, however, associated with an incomplete inhibition of the motor command that would provide a consistent explanation for the recording of muscular activity during MI. Despite the fact that the neural mechanisms have yet not been clearly identified, two hypotheses may be stated: First, the inhibitory mechanisms are effective before sending the information, elaborated within the associate cortices, to the primary motor cortex.

Especially this inhibition may originate from the prefrontal cortical areas associated with limbic structures and cingulate cortices (the behavioural inhibition system early postulated by

Gray, 1990). This behavioural system has other connections with the parietal association cortices involved in No-Go performance (Watanabe et al., 2002). Second, inhibitory mechanisms may also be active at different subcortical levels including the spinal cord (Bonnet et al., 1997), the brainstem, and the cerebellum (Lotze et al., 1999).

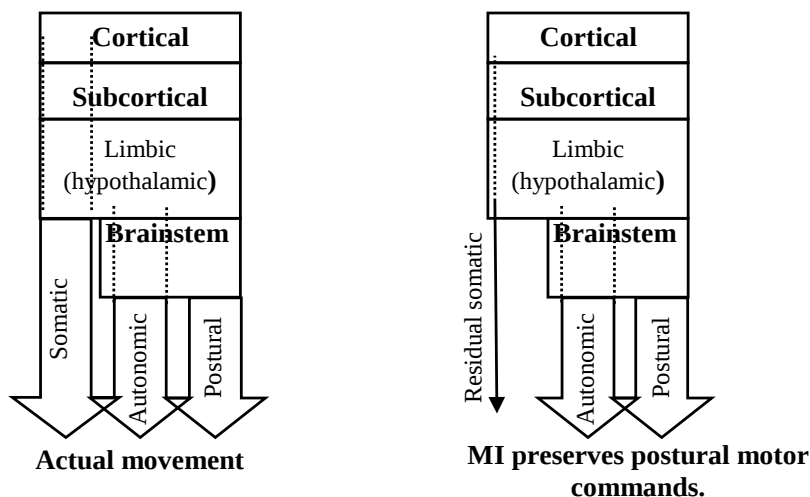


Figure 8. Schematic representation of a somatic motor command actually addressed to muscles with integrated i) postural commands controlled by the brainstem and ii) autonomic commands from the limbic system associated with the hypothalamus (on the left). The phasic command is inhibited partially during motor imagery, whereas the autonomic commands remain identical to that held by the autonomic nervous system to ensure actual execution (on the right).

While performing MI, the tasks from our 3 experiments were found to differentially affect somatic and autonomic motor commands. The most important result is that a specific subliminal muscle activity was seen during MI, as it seems obvious that a cognitive operation should have little influence on more automated regulations (postural and autonomic regulations controlled at infra- and unconscious levels, respectively). From the intention to act, direct voluntary commands are normally transmitted through the pyramidal tract to elicit movement. The process of an incomplete inhibition that accompanies MI remained unsolved, although it may be hypothesized that such a process is aimed at organising peripheral effectors during the preparation phase of the forthcoming actual execution. Duclos et al. (2008) have evidenced anticipatory changes in patterns of human motoneurons discharge during motor preparation. This may also be observed during MI. Conversely, Bonnet et al.'s (1997) view is that MI should be compared to action, rather than to motor preparation, hence considering MI as the intention to avoid movement execution, although MI might be more closely related to pre-executive processes of a movement than its actual execution (e.g. Hanakawa et al. 2008). Michelon et al. (2006) underlined that the MI process does not necessarily require a motor simulation which would integrate the mapping of the effector-specific commands required to achieve the movement. This would be a quite different MI as that followed by actual execution. The close relationship (temporal, structural) between MI and actual execution is in favour of an upstream organization of inhibition, implying the behavioural inhibition system. This would also explain why the most automated parts of

movement commands are not inhibited, as they are controlled at the subcortical level. Nevertheless, Bonnet et al. (1997) and Jeannerod (2006) stated that the inhibitory mechanisms may also be localised downstream of the motor cortex, *e.g.* at the spinal cord or brainstem level. In addition, Lotze et al. (1999) postulated that the posterior cerebellum might also play a crucial role in the inhibition of the motor command. There are probably several systems and processes of motor inhibition, coordinated at different levels of the central nervous system from the premotor cortex to the spinal cord. The question of a selective inhibition which could explain the subliminal muscle activity and even the somatic commands from the low levels of the central nervous system (*e.g.*, controlling postural regulations) remains to be asked.

Incomplete inhibition of motor commands was confirmed by data from the force plate (experiment 2), suggesting that when a movement requires postural adjustments, these are not inhibited during MI. These results seem more easily explainable as postural adjustments mainly depend on sensori-motor processes. However, the cognitive processes may also have an important role in such postural adjustments. This would show that mental processes, like MI, have no real effect on automatic sensori-motor processes usually associated with voluntary motor commands. The same conclusion could be drawn with reference to the autonomic nervous system regulation (experiment 3): motor commands which are sent to the autonomic effectors are not inhibited during MI.

All experiments provided evidence of an incomplete inhibition of the motor commands addressed to the different effectors. This finding should be used in mental rehearsal program. In sport training, for example, one must preserve motor resources to prevent overtraining, and MI is thought as being a reliable tool associated with actual practice to be integrated in training program. In the field of clinical rehabilitation (whatever the nature of the stroke, either peripheral or central), MI use is known to improve functional recovery (*e.g.* Braun et al., 2006; Zimmermann-Schlatter et al., 2008). Further research should also investigate the processes of somatic motor commands inhibition, since no experimental investigation has been specifically focused on where and how motor commands might be inhibited during MI.

REFERENCES

- Aruin, A., Mayka, M., Shiratori, T. (2003). Could a motor action that has no direct relation to expected perturbation be associated with anticipatory postural adjustments in humans? *Neuroscience Letters* 341, 21-24.
- Bakker, F.C., Boschker, M.S. and Chung, T. (1996). Changes in muscular activity while imaging weight-lifting using stimulus or response propositions. *Journal of Sport and Exercise Psychology*, 18, 313-24.
- Bonnet, M., Decety, J., Jeannerod, M. and Requin, J. (1997). Mental simulation of an action modulates the excitability of spinal reflex pathways in man. *Cognitive Brain Research*, 5, 221-228.
- Boschker, M.S.J. (2001). *Action-based imagery: on the nature of mentally imagined motor actions*. (Amsterdam: Ipskamp Printpartners).

- Braun, S.M., Beurskens, A.J., Borm, P.J., Schack, T., Wade, D.T. (2006). The effects of mental practice in stroke rehabilitation: a systematic review. *Archives of Physical Medicine Rehabilitation*, 87, 842-852.
- Collet, C., Dittmar, A., Vernet-Maury, E. (1999). Programming or inhibiting action: evidence for differential autonomic nervous system response patterns. *International Journal of Psychophysiology*, 32, 261-276.
- Decety, J. (1996). Do imagined and executed actions share the same neural substrate? *Cognitive Brain Research*, 3, 87-93.
- De Jong, R., Coles, M.G.H., Logan, G.D., Gratton, G. (1990). In search of the point of no return: the control of response processes. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 164-182.
- Duclos, Y., Schmied, A., Burle, B., Burnet, H. and Rossi-Durand, C. (2008). Anticipatory changes in human motoneuron discharge patterns during motor preparation. *Journal of Physiology*, 586, 1017-28.
- Ehrenfield, T., Guerraz, M., Thilo, K.V., Yardley, L., Gresty, M.A. (2003) Posture and mental task performance when viewing a moving visual field. *Cognitive Brain Research* 17, 140-153.
- Fang, Y., Siemionow, V., Sahgal, V., Xiong, F., Yue, G.H., (2001). Greater movement-related cortical potential during human eccentric versus concentric muscle contractions. *Journal of Neurophysiology*, 86, 1764-1772.
- Gray, J.A. (1990) Brain systems that mediate both emotion and cognition. *Cognition & Emotion*, 4, 269-288.
- Guillot, A., Collet, C. (2005). Contribution from neurophysiological and psychological methods to the study of motor imagery. *Brain Research Reviews*, 50, 387-97.
- Guillot, A., Lebon, F., Rouffet, D., Champely, S., Doyon, J. & Collet, C. (2007). Muscular responses during motor imagery as a function of muscle contraction types. *International Journal of Psychophysiology*, 66, 18-27.
- Guillot, A., Collet, C. (2008). Construction of the motor imagery integrative model in sport: a review and theoretical investigation of motor imagery use. *International Review of Sport and Exercise Psychology*, 1, 31-44.
- Hanakawa, T., Dimyan, M.A. and Hallett, M. (2008). Motor planning, imagery, and execution in the distributed motor networks: a time-course study with functional MRI. *Cerebral Cortex*, in press.
- Hugdahl, K. (1996). Cognitive influences on human autonomic nervous system function. *Current Opinion in Neurobiology* 6, 252-258.
- Jeannerod, M. (1994). The representing brain: neural correlates of motor intention and imagery. *Behavioural Brain Sciences*, 17, 187-245.
- Jeannerod, M. (2006). *Motor Cognition*. Oxford University Press.
- Komi, P.V., Linnamo, V., Silventoinen, P., Sillanpää, M. (2000). Force and EMG power spectrum during eccentric and concentric actions. *Medicine Science in Sports & Exercise*, 32, 1757-1762.
- Kummer, W. (1992). Neuronal specificity and plasticity in the autonomic nervous system. *Annals of Anatomy*, 174, 409-417.
- Lee, W.A. (1980). Anticipatory control of postural and task muscles during rapid arm flexion. *Journal of Motor Behavior*, 3, 185-196.

- Le Pellec, A., Maton, B. (2002). Initiation of a vertical jump: the human body's upward propulsion depends on control of forward equilibrium. *Neuroscience Letters*, 323, 183-186.
- Linnamo, V., Strojnik, V., Komi, P.V. (2006). Maximal force during eccentric and isometric actions at different elbow angles. *European Journal of Applied Physiology*, 96, 672-678.
- Lotze, M., Montoya, P., Erb, M., Hülsmann, E., Flor, H., Klose, U., Birbaumer, N., Grodd, W. (1999). Activation of cortical and cerebellar motor areas during executed and imagined hand movements: an fMRI study. *Journal of Cognitive Neuroscience*, 11, 491-501.
- Marsh, A.P., Geel, S.E. (2000). The effect of age on the attentional demands of postural control. *Gait Posture*, 12, 105-113.
- McHugh, M.P., Tyler, T.F., Greenberg, S.C., Gleim, G.W. (2002). Differences in activation patterns between eccentric and concentric quadriceps contractions. *Journal of Sports Science*, 20, 83-91.
- Michelon, P., Vettel, J.M. and Zacks, J.M. (2006). Lateral somatotopic organization during imagined and prepared movements. *Journal of Neurophysiology*, 95, 811-22.
- Mulder, T., Zijlstra, S., Zijlstra, W. and Hochstenbach, J. (2004). The role of motor imagery in
- Porges, S.W. (1995). Orienting in a defensive world: mammalian modifications of our evolutionary heritage. A polyvagal theory. *Psychophysiology*, 32, 301-316.
- Redfern, M.S., Jennings, J.R., Martin, C., Furman, J.M. (2001). Attention influences sensory integration for postural control in older adults. *Gait and Posture*, 14, 211-216.
- Riley, M.A., Baker, A.A., Schimt, J.M. (2003). Inverse relation between postural variability and difficulty of a concurrent short-term memory task. *Brain Research Bulletin*, 62, 191-195.
- Roure, R., Collet, C., Deschaumes-Molinaro, C., Delhomme, G., Dittmar, A., Vernet-Maury, E. (1999). Imagery quality estimated by autonomic nervous system response is correlated to sporting performance enhancement. *Physiology and Behavior*, 66, 63-72.
- Sequeira, H., Ba-M'hamed, S. (1999). Pyramidal control of heart rate and arterial pressure in cats. *Archives Italiennes de Biologie*, 137, 47-62.
- Teasdale, N., Bard, C., Larue, J., Fleury, M. (1993). On the cognitive penetrability of postural control. *Experimental Aging Research*, 19, 1-13.
- Wallin, B.G., Fagius, J. (1986). The sympathetic nervous system in man: aspects derived from microelectrode recordings. *Trends in Neuroscience*, 9, 63-67.
- Watanabe, J., Sugiura, M., Sato, K., Sato, Y, Maeda, Y., Matsue, Y., Fukuda, H., Kawashima, R. (2002). The human prefrontal and parietal association cortices are involved in NO-GO performances: an event-related fMRI study. *Neuroimage*, 17, 1207-1216.
- Woollacott, M., Shumway-Cook, A. (2002). Attention and the control of posture and gait: a review of an emerging area of research. *Gait and Posture*, 16, 1-14.
- Zimmermann-Schlatter, A., Schuster, C., Puhan, M.A., Siekierka, E., Steurer, J. (2008). Efficacy of motor imagery in post-stroke rehabilitation: a systematic review. *Journal of Neuroengineering and Rehabilitation*, 14, 8.

Chapter 20

RATIONALITY: THE DESIRE FOR AN ABSOLUTE WITHOUT A CAUSE

Todd McElroy¹, Jacob Conrad and Dominic Mascari³

^{1,3}Appalachian State University, Boone, NC, US

The irrationality of a thing is no argument against its existence, rather a condition of it.

Friedrich Nietzsche

German philosopher (1844 - 1900)

Friedrich Nietzsche depicts us as creatures bound by an irrational determinism.

This ascription to irrational forces is commonplace and many, if not most, people adhere to this belief. Such a belief is not surprising in light of how the unconscious was, for many years, thought of as a mythical, dark place where sadistic urges and sexual perversions resided. These terrifying forces, however, were reportedly kept at bay by a surrealistic chasm that lies just between conscious realization and the dark abode of unbounded hedonistic acceptance. Not a pretty picture considering that the unconscious constitutes a large part of what it means to be human.

Taking such a position, as some do, seems troubling to those trying to further a scientific understanding of human psychology. Practically speaking, if we are bound by such a circumstantial existence then why strive for more? In other words; why should we place such effort in making better decisions when the choices that we make will inevitably be tainted by irrational concomitance with unconscious forces?

In this chapter we take a very different view, following a broad perspective that portrays predecisional thought as one of cooperation between two forces working toward a common outcome. Rather than ascribing our fate to the inescapable void of irrational fallibility, we make the case that decision choice can be better understood by approaching it as a complementary superordinate process and perhaps, at times, a contradictory process. Nevertheless, the essence of the decision process is always an interactive product of conscious and unconscious influences. We believe that furthering the understanding of this

dualistic pairing will allow us to achieve a better understanding of decision processing and allow for more optimal decision making.

Why are we not rational? This question seems at first insulting and even perfunctory at times. In fact, one can just as easily posit the question: how often is it that we actually need to be rational? In a world that has built-in guides for many of our motivations and desires, it is arguable that we do not really need to spend a great deal of effort on improving and trying to understand this question. If one merely acquiesces to the forces that direct them then no further contemplation is needed. Thankfully, many people are not satisfied with relaxing in the flow of life's river.

In an attempt to address this question we make the assertion that much of the decision making operation is carried out by unconscious processing. In direct contradiction to what most people have succumbed to as *reality*, we propose that our view of the world is colored by the unconscious lens through which it is viewed. In short, we are creatures making choices to and fro but we are largely unaware of the forces that lay out direction for those choices. And because we lack perceptual awareness of this, it is probably the case that this is an *ad hominem* artifact. The most likely reason for such an arrangement is that a lack of such awareness leaves us with the security of directing ourselves, rather than being the object of direction.

Evidence of this can be found in the understanding that we rarely do things that are thoroughly thought out. If a person gives this proposal due regard they will quickly realize that, more often than not, they do things without thinking. We do not have knowledge of why we are doing a particular act or behavior. Rather we are functioning to fulfill some goal or motive that has been set in motion. This behavior is initiated and staged by a process that is unbeknownst to us. Imagine how we would function if we gave thought to our every motion?

Further, imagine if we walked around in life with a full spectrum of our world. That is to say, if we consistently walked through life with an elaborated notion of where we are and our future intentions of what we hope to achieve. How much room would be left for any other unexpected occurrences, or merely appreciating the many aspects of life that bring so much joy to the experience? No, it seems more likely that we are creatures who simply rely on feelings of direction and goals rather than thinking most acts through.

While this seems to call into question the essential assumption of autonomous human beings, we make the case that this is not an exception to humanity but rather it is the rule. Ironically, it is more likely that we are driven largely by aspects of our self that are not conscious to us; by forces which allow us to function as the human beings that we are.

In fact, one could argue that what it is to be human is best described in terms of the complimentary (or at times contradictory) interaction between the conscious and unconscious. So how can we come to better understand this process that holds such promise of insight for rational understanding? It is our proposition that a better understanding can be gained through observing the choice per se as a decision process established as a means that is derived and made within, and in light of, the larger directionality determined by the ends that we seek.

We view the "means" as largely decided by the conscious and the "end" as directed by the unconscious. People behave with regard to the means and are predestined by unconscious forces to seek achievement of the end. The direction of the unconscious impetus is by and large not something that we are privy to in our conscious deliberation. It is well known in decision making research that we often act and make decisions based upon feelings and heuristics rather than analytic thought. Based upon this understanding it is reasonable to

propose that we very often act in accordance with a directive that is laid out for us by an unconscious; an unconscious that has a predictable goal that is directed to achieve a desirable end. A goal encrypted by an unconscious director. A direction not filled with trickery or pejorative ends but one that helps us along our path and clears a way for a more achievable end.

In sum, we are attempting to address the assumption that most people believe their decision making is guided by conscious thinking; evaluating prospects of a given situation and, after a thoughtful analysis, choosing the option that they most prefer. Contrary to this belief, we propose that humans are surrounded by unconscious goals and motives that are directing them toward a desired outcome. We make the proposal that the conscious nature of these actions can only be understood to the extent that it exists within a particular goal setting. In other words, the impetus for a decision choice is being directed by unconscious forces. And while we are conscious of particular behaviors and preferences directed toward a decision, we are not privy to the goal setting. Why is this important the reader might ask? The importance of this understanding lies in the fact that the goal setting can have profound influences on decisions that are based within the same parameters with only the goal differing between them. And these choice preferences are the behavioral manifestations that we point to as defining rationality.

OVERVIEW OF TOPICS

What constitutes a "rational" act of choice has roots as deep as those of humanity. To make the best choice in a given situation is paramount in many, if not most, situations. It is not surprising that so much research has been devoted to understanding the virtues of this process. To address our current investigation we first provide an overview of how rationality is thought of in decision making research. Next, we discuss some relevant research on the associations and dissociations between conscious and unconscious processing, including the automaticity of goals. Afterward we discuss prospect theory, framing effects and formulate a general statement and hypothesis derived from current research. We then report and discuss the implications of these findings.

The rationality of decision making. Recent research investigating rational decision making first pointed to a means for describing rational choice. Admirable attempts by classic decision theorists have attempted to describe decision choice objectively (Bernoulli, 1954). Taking personal values into account later theorists incorporated individual value attached to the outcome (Von Neumann and Morgenstern, 1947), the person (Savage, 1954; Schmeidler, 1989) and more recently the interaction between the two (Kahneman and Tversky, 1979). While these attempts have made immeasurable advancements at understanding rational choice, it is clear that much more can be learned about the process of rational choice.

The normative and prescriptive approaches. Searching for what the best decision is has two central approaches in psychology and decision-making research. The normative approach refers to is more descriptive in its contents and relies on an ideal model, normally mathematical in form, and is used as a basis for determining what the right choice is. This approach is statistically based and has its form in expected value and expected utility models for rational decision making. As the reader can easily surmise people do not always adhere to

such mathematical models for choosing the correct or "rational" choice. The alternative or prescriptive approach attempts to incorporate these deviations. With a normative theory as a comparison basis we can attempt to better see the faulty decisions that people make and seek means for establishing a better strategy for understanding decision making and people's deviations thereunto. In a sense, we can prescribe how the model should adapt to the deviations.

Prescriptive approaches to decision making are less abundant in research investigating rational decision making but when they do exist they are normally designed to help people see their faulty decision making and to adept means for more rational choice. There are certainly many applied advantages to this strategy such as individuals interested in clinical and organizational settings. While attempts at improving human judgment are admirable, the success of such work is debatable and may be limited to related contextual settings. Nevertheless, it is important to apply the findings and knowledge of research in rational choice and this certainly represents a viable means for doing so.

THE POWER OF UNCONSCIOUS AND CONSCIOUS PROCESSING: WHO IS BETTER?

The question of whether the conscious or unconscious has greater ability to lead optimal decisions is an interesting one. Yet until recently it was largely assumed that conscious processing was superior in most respects for making decisions. Research by Dijksterhuis and colleagues (e.g., Dijksterhuis, 2004; Dijksterhuis, Bos, Nordgren, and van Baaren, 2006; Dijksterhuis, and van Olden, 2006; Dijksterhuis and Meurs, 2006; Dijksterhuis, Nordgren, 2006) challenged this assumption. Their studies have provided evidence that, on the surface, seem counterintuitive for what most people would think of as the best way to make decisions. In their studies they constructed situations so that some participants were under conditions with limited cognitive resources (e.g., time constraint) whereas others had unconstrained cognitive resources (e.g., no time constraint). It is largely assumed that when cognitive resources are constrained, people will rely upon unconscious processing to make their decisions. Across these studies what they found was that when participants had ample opportunity to think about their decisions, they actually performed more poorly (i.e., made less optimal decisions) as compared to those participants whose cognitive resources were constrained.

At the heart of these studies is the proposition that unconscious processing ability exceeds that of conscious processing in making decisions. This finding is challenging to what most of us think of as good decision making. Specifically, we have been taught that we should think our decisions through and not make "hasty" choices. While this finding certainly is important for furthering the understanding of decision making, recent research has challenged this effect. Research by Acker (2008) has suggest that this finding is limited in scope.

Acker (2008) demonstrated through empirical investigation that the decision making advantage of unconscious processing for attaining normative standards in decision choice may be less than what had been previously reported. This finding provided the impetus for a meta analysis which revealed that a superior decision making advantage for unconscious

processing did not seem to be the case. Rather there may be certain conditions under which each may have a processing advantage.

Unconscious goal activation: are we aware of what we want? When a prime is presented without conscious awareness research has shown that it has real and measurable effects on later judgments (Bargh, 1984). That is, without the person being consciously aware, subliminally presented stimuli influence a person's reaction toward a particular target that is otherwise ambiguous target (e.g., Stapel and Koomen, 2005).

The literature investigating the conscious nature of goals indicates that goals for a particular task are largely unconscious (Aarts, and Dijksterhuis, 2000; Bargh, Gollwitzer, Lee-Chai, Barndollar and Trötschel, 2001; Chartrand, and Bargh, 1996; Moskowitz, Li, and Kirk, 2004). For example, Lakin and Chartrand (2003) found that goals to affiliate with other people lead to more mimicry of another person (Lakin Chartrand and Arkin 2006). In a similar manner, the decision for selecting a goal in habit formation is strongly related to unconscious goals (e.g., Aarts and Dijksterhuis, 2000; Bargh, 1990).

Across this research a theme that emerges is that when a goal is primed it activates an adjustment to the contextual conditions which are rendered to the individual. Take for example research by Aarts and Dijksterhuis (2003) they found that the goal that was primed activated a particular way for individuals to behave and respond in a given social context. Taking this line of thinking one step farther, it is reasonable to assume that, when a person is primed with a particular goal, it will influence how they respond and interpret the context of particular decision task that they are encountering.

PROSPECT THEORY

By and large most recent attempts at understanding rational decision making have focused on violations of normative standards (e.g., Von Neumann and Morgenstern, 1947). However, over the last several decades the tide of research investigating rational decision making has shifted and now many lines of research derive their bases from the tenants of prospect theory. Prospect theory was first proposed by Kahneman and Tversky (1979) as a means for describing and understanding how people evaluate options and make decisions. Since that time, prospect theory has become the leading alternative for explaining rational decision-making. Prospect theory differs from the very narrow, logical approach embraced by earlier theories (e.g., Von Neumann and Morgenstern, 1947) by allowing for differences in subjective value and perception of alternatives.

Prospect theory is sensitive to the psychological implications of decision-making. This is most well defined by how the perceivers interpretation of the problems alternatives as either gains or losses. Prospect theory proposes that gains and losses are represented differently. The ultimate result of this difference perceived domain is that different subjective value is assigned to the target of the decision task. These differences in personal value are what lead individuals have to gains and losses that provide the framework for interpreting framing effects.

According to prospect theory (Kahneman and Tversky, 1979) the process of decision-making consists of two phases. The first phase involves editing of the alternatives and occurs very early in the decision making process. The characteristic aspects of this phase are

simplification and reorganization of the options. And the simplification and reorganization allows the options to be coded as gains or losses relative to a neutral reference point. The subsequent phase involves evaluation and editing of options. In this phase the assigned values and weighted probabilities for the options are evaluated relative to the prior editing phase. At this point the subjective values and probabilities are then combined into a single value and are then compared and contrasted relative to each other.

The ultimate end to this process is what has become known as "framing effects" According to prospect theory framing effects are depicted by an S-shaped value function. The function is concave when the alternatives focus on gains and convex for loss based alternatives. This allows for the prediction that when the problem is framed positively, in terms of gains people will be risk-averse whereas when the problem is framed negatively people tend to be risk-seeking. For example, a person in the concave (gains) curve should prefer gaining 100 dollars for certain rather than a 50/50 chance to gain 200 or gain nothing. On the other hand, a person in the convex curve should prefer a 50/50 chance to lose 200 dollars or lose nothing rather than losing 100 dollars for certain.

The prospect theory account of rational decision making is particularly informative because it can account for these apparent discrepancies that arise between human choice preference and what normative theories dictate. For example, consider the same type of framing problem from an expected utility theory approach. According to this type of approach, options that contain the same expected utility should be treated as equivalent regardless of the frame in which they are presented. So according to expected utility the framing of alternatives should have no influence on a decision maker's choice. Because there is a great amount of research supporting the framing effect (See Kuhberger, 1998 and Levin, Schneider, and Gaeth, 1998 for reviews) it is widely assumed that the framing effect is the paramount example of irrationality.

Because prospect theory and framing research holds such importance for understanding human rationality, an area devoted to understanding how the framing effect functions has developed. Research in this area has explored many different aspects of the framing effect and while no encompassing theory has been proposed, much advancement in the field has lead to a better understanding of the framing effect.

Framing research. Research in the area of framing effects has demonstrated the profound effect that context can have on the framing effect (Takemura, 1994; LeBoeuf and Shafir, 2003; McElroy and Mascari, 2007; Sieck and Yates, 1997). Take for example research by Bless, Betxch, and Franzen (1998), they found that when the word "statistics" as compared to "medicine" was placed in the upper corner of the paper, this simple contextual manipulation acted to attenuate framing effects from occurring

While context has shown to have important influences on the framing effect, that does not cover the other aspect of the decision world; the internal aspect. Specifically, research has revealed that individual difference factors such as need for cognition (Curseu, 2006; Smith and Levin, 1996; Zhang and Buda, 1999; Simon, Fagley, and Halleran, 2004), intuition (Levin, Gaeth, and Schreiber, 2002), collective identity (McElroy and Seta, 2006) and predispositions toward analytical-deliberative thought (Bartels, 2006; LeBoeuf and Shafir, 2003, McElroy and Seta, 2003) all influence the likelihood that framing effects will occur. The importance of individual difference factors has been growing in the last several years and has revealed much about how individuals vary in their perception and processing of a decision task. For example, consider research by McElroy and Seta (2007) where they

showed that high self-esteem individuals tend to be relatively unbiased in the valence that they impose onto a decision task whereas low self-esteem individuals tend to impose negative valence onto the decision task. Consequently, low self-esteem individuals tend to be more risk-seeking in traditional framing scenarios.

Other researchers hoping to better understand the framing effect have focused on processing involved in framing. Most research devoted to this topic has proposed that different styles of thinking can lead to more or less reliance on the framing of a decision problem. Not surprisingly, most of this research has attempted to apply a dual-processing approach to understand the framing effect. One approach by Igou and Bless (2007) suggests that when decision makers utilize constructive processing strategies to determine the meaning of the problem they will seek out contextual information (e.g., the frame) and use it to “go beyond” the information in the problem. According to this view, as task relevance increases so should reliance on the frame. Reyna and Brainerd (1991) have proposed that memory retrieval occurs along a continuum, from verbatim to gist-like. Gist retrieval operates through long-term memory and relies more on representations of personal values and preferences whereas verbatim retrieval involves a more objective approach to the problem. In this account when an individual is presented with a decision-task of low importance, they will rely more upon the decision frame for making decisions as compared to when the task is high in personal relevance. The analytic-holistic model McElroy and Seta (2003; 2004) proposes that when the task is high in personal relevance individuals will rely more on an effortful-analytic style of processing which will lead to greater numeric sensitivity and little or no framing influence whereas low personal relevance leads to less effortful-holistic processing and heightened sensitivity to contextual cues such as the decision frame.

Recent research by McElroy and Seta (2007) has revealed that the direction of the framing effect can only be determined with respect to the person’s goal for the decision task. Specifically, McElroy and Seta demonstrated that the goal of the decision task can determine whether a relative gain or loss is perceived as a psychological gain or loss. According to this research, when the goal of the task is to increase the commodity at stake, gains are perceived as gains and losses as losses and typical framing effects are observed. However, when the goal is to decrease the target of the task, gains are then perceived as losses and losses are perceived as gains. And when this situation occurs the typical framing effect is reversed. Thus, this research provides an important new piece of understanding.

AN EMERGING QUESTION

One question that emerges from the literature is whether the goal of the decision maker is automatic (unconscious) and whether this unconscious goal will then influence choice preference in a manner consistent with prior research (McElroy and Seta, 2007). Remember that McElroy and Seta found that the goal of the decision maker (increase or decrease) determined the direction of the framing effect. However, it is not clear whether the goal of the participants is something that they are consciously aware of or whether it is something outside of their awareness. If the goal of the decision task is something that is unconscious then this has important implications for those seeking a more full understanding of the framing effect such that, the perceived gain or loss of a decision task is determined by unconscious

processing. This is a novel finding and adds to the literature for those researchers investigating the framing effect. To examine this important question we performed a study to examine that nature of conscious and unconscious processing in a typical framing task.

METHOD

Participants and Design. One hundred and eight students volunteered to take part in the study. Participants received course credit for their efforts. The design of our study included a 2 frame (gain, loss) x 2 primed goal (increase, decrease) between-subjects factorial design.

Procedure and materials. Participants in our study were first given a word-find task similar to what has been used in prior research (Bargh, Chen and Burrows, 1996). The words that participants were asked to seek focused on either increasing or decreasing. For example, words related to increasing included; amplify, extend and multiply whereas words related to decreasing included; abate, reduce and lower. After completing the anagram task participants were provided with a decision task similar to that used by McElroy and Seta (2007). However, the task was slightly modified to remove any words that indicated whether the goal of the task was to increase, maintain or decrease. As prior research has shown (McElroy and Seta, 2007) this task is amenable to either of the directions. Specifically, the task read as follows:

Imagine that you are an athlete with the goal of changing your weight as much as possible. Because of your sport, the more you change your weight the better you can perform. At this juncture of the season you have to begin a specialized training program and you must choose between the following two programs. Assume that the following alternatives represent the exact estimates for each training program.

Directly afterward this information, participants were presented with the two decision alternatives similar to other risky-choice framing tasks. They were then asked to rate their opinion of the alternatives on a 7-point scale where 1 represented "definitely would recommend A" and 7 represented "definitely would recommend B".

RESULTS

To determine whether the primed goal influenced participants' choice preference for the frame, we performed an analysis of variance on the data. Primed goal (increase, decrease) and decision frame (gain, loss) acted as our independent variables and risky-choice preference was our dependent variable. The results of this analysis revealed a significant interaction between these two variables $F(1, 104) = 4.5, p < .05$, no significant main effects occurred. As may be seen in Table 1, when participants were primed with an "increase" goal, they demonstrated typical framing effects, risk aversion for gains and risk seeking for losses. However, when participants were primed with a "decreasing" goal, our findings revealed that the effect for framing was opposite to what is typically found in the literature. The results of this study are consistent with prior research investigating the effect of goals on framing (McElroy and Seta, 2007). However this research extends this understanding by

demonstrating that individuals are not aware of the goals that they bring to a decision task, the unconscious nature of goals and the subsequent effect on rational choice and framing effects furthers the understanding of rationality.

Table 1. Average choice preference as a function of primed goal and gain/less frame

Gain frame Loss frame				
	N	Mean	N	Mean
Problem goal:				
Increase	28	2.3	27	2.7
Decrease	27	3.5	26	2.5

CONCLUSION

In this chapter we have provided the framework for developing a dualistic view for decision making. At the heart of this view lies our proposal that people are guided by both conscious thinking as well as unconscious processing. We propose that human beings are guided by unconscious goals that direct many, if not most, of our decision choices. When we consciously evaluate decision choices we do so in light of parameters provided to us by the unconscious. Taken together, we suggest that understanding the decisions that we make can only be understood if they are viewed through a lens of an unconscious goal setter that sets the stage for the decisions that we make.

REFERENCES

- Aker, F. (2008). New findings on unconscious versus conscious thought in decision making: additional empirical data and meta-analysis. *Judgment and Decision Making*, 3(4), 292-303.
- Aarts, H. and Dijksterhuis, A. (2000). Habits as knowledge structures: automaticity in goal directed behavior. *Journal of Personality and Social Psychology*, 78, 53-63.
- Aarts, H. and Dijksterhuis, A. (2000). The automatic activation of goal directed behaviour: The case of travel habit. *Journal of Environmental Psychology*, 20, 75-82.
- Aarts, H. and Dijksterhuis, A. (2003). The silence of the library: Environment, situational norm, and social behavior. *Journal of Personality and Social Psychology*, 84, 18-28.
- Bargh, J. A. (1984). Automatic and conscious processing of social information. In R. S. Wyer, Jr, and T. K. Srull (Eds.), *Handbook of social cognition* (Vol. 3, pp. 1-43). Hillsdale, NJ: Erlbaum.
- Bargh, J. A. (1990). Auto-motives: Preconscious determinants of social interaction. In T. E. Higgins and R. M. Sorrentino, Eds. *Handbook of Motivation and Cognition: Foundations of Social Behavior* Vol. 2. (pp. 93-130). New York: Guilford Press.
- Bargh, J. A., Chen, M. and Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait constructs and stereotype activation on action. *Journal of Personality and Social Psychology*, 71, 230-244.

- Bargh, J. A., Gollwitzer, P. M., Lee-Chai, A., Barndollar, K. and Trötschel, R. (2001). The automated will: Nonconscious activation and pursuit of behavioral goals. *Journal of Personality and Social Psychology*, 81, 1014-1027.
- Baron, J. (1993). Why teach thinking? An essay. *Applied Psychology: An international Review*, 42, 191-214.
- Baron, J. (2000). *Thinking and deciding* (3rd ed.). New York, NY: Cambridge University Press.
- Bartels, D. M. (2006). Proportion dominance: The generability and variability of favoring relative savings over absolute savings. *Organizational Behavior and Human Decision Processes*, 100, 76-95.
- Bernoulli, D. (1954). Exposition of a new theory of the measurement of risk (L. Sommer, Trans.). *Econometrica*, 22, 23-26. (Original work published 1738).
- Chartrand, L. and Bargh, J. A. (1996). Automatic activation of impression formation and memorization goals: Nonconscious goal priming reproduces effects of explicit task instructions. *Journal of personality and social psychology*, 71, 464-478.
- Curseu, P. L. (2006). Need for cognition and rationality in decision-making. *Studia Psychologica*, 48, 141-156.
- Dijksterhuis, A. (2004). Think different: The merits of unconscious thought in preference development and decision making. *Journal of Personality and Social Psychology*, 87, 586-598.
- Dijksterhuis, A., Bos, M. W., Nordgren, L. F. and van Baaren, R. B. (2006). On Making the Right Choice: The Deliberation-Without-Attention Effect. *Science*, 311, 1005-1007.
- Dijksterhuis, A. and Meurs, T. (2006). Where creativity resides: The generative power of unconscious thought. *Consciousness and Cognition*, 15, 135-146.
- Dijksterhuis, A. and Nordgren, L. F. (2006). A Theory of Unconscious. *Perspectives on Psychological Science*, 1, 95-109.
- Dijksterhuis, A. and van Olden, Z. (2006). On the benefits of thinking unconsciously: Unconscious thought can increase post-choice satisfaction. *Journal of Experimental Social Psychology*, 42, 627-631.
- Igou, E. R. and Bless, H. (2007). On undesirable consequences of thinking: Increased framing effects as a function of substantive processing. *Journal of Behavioral Decision Making*, 20, 125-142.
- Kuhberger, A. (1998). The influence of framing on risky decisions: A meta-analysis. *Organizational Behavior and Human Decision Processes*, 75, 23-55.
- Lakin, J. L. and Chartrand, T. L. (2003). Using nonconscious behavioral mimicry to create affiliation and rapport. *Psychological Science*, 14, 334-339.
- LeBoeuf, R. A. and Shafir, E. (2003). Deep thoughts and shallow frames: On the susceptibility to framing effects. *Journal of Behavioral Decision Making*, 16, 77-92.
- Levin, I. P., Gaeth, G. J., Schreiber, J. and Lauriola, M. (2002). A new look at framing effects: Distribution of effect sizes, individual differences, and independence of types of effects. *Organizational Behavior and Human Decision Processes*, 88, 411-429.
- Levin, I. P., Gaeth, G. J., Schreiber, J. and Lauriola, M. (2002). A new look at framing effects: Distribution of effect sizes, individual differences, and independence of types of effects. *Organizational Behavior and Human Decision Processes*, 88, 411-429.

- Levin, I. P., Schneider, S. L. and Gaeth, G. J. (1998). All frames are not created equal: A typology and critical analysis of framing effects. *Organizational Behavior and Human Decision Processes*, 76, 149-188.
- Libet, B., Gleason, C.A., Wright E.W. and Pearl, D.K. (1983). Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential). The unconscious initiation of a freely voluntary act, *Brain* 106, 623-642.
- McElroy, T. and Mascari, D. (2007). When is it going to happen? How temporal distance influences processing for risk-choice framing tasks. *Social Cognition*, 25, 550-572.
- McElroy, T., and Seta, J. J. (2003). Framing effects: An analytic-holistic perspective. *Journal of Experimental Social Psychology*, 39, 610-617.
- McElroy, T., and Seta, J. J. (2004). On the other hand am I rational? Hemispheric activation and the framing effect. *Brain and Cognition*, 55, 572-580. (Reprinted in Complexity Digest issue 2004.28).
- McElroy, T., and Seta, J. J. (2006). Does it matter if it involves my group? How the importance of collective-esteem influences a group-based framing task. *Social Cognition*, 24, 319-333.
- McElroy, T., Seta, J. J. (2007). Framing the frame: How task goals determine the likelihood and direction of framing effects. *Judgment and Decision Making*, 2, 251-256.
- Moskowitz, G. B., Li, P., and Kirk, E. R. (2004). The Implicit Volition Model: On the Preconscious Regulation of Temporarily Adopted Goals. In: *Advances in experimental social psychology*, Vol. 36. Zanna, Mark P.; San Diego, CA, US: Elsevier Academic Press, pp. 317-413.
- Sanfey, A.G., Rilling, J.K., Aronson, J.A., Nystrom L.E. and Cohen, J.D. (2003). The neural basis of decision-making in the Ultimatum Game, *Science* 300, 1755-1758.
- Savage, L. J. (1954). *The foundations of statistics*. New York: Wiley.
- Schmeidler, D. (1989). Subjective probability and expected utility without additivity. *Econometrica*, 57, 571-587.
- Sieck, W., and Yates, J.F. (1997). Exposition effects on decision making: choice and confidence in choice. *Organizational Behavior and Human Decision Processes*, 70, 207-219.
- Simon, A. F., Fagley, N.S., and Halleran, J.G. (2004). Decision framing: Moderating effects of individual differences and cognitive processing. *Journal of Behavioral Decision Making*, 17, 77-93.
- Smith, S. M., and Levin, I.P. (1996). Need for cognition and choice in framing effects. *Journal of Behavioral Decision Making*, 9, 283-290.
- Stapel, D. A., and Koomen, W. (2005). Multiple ambiguity and an impression formation focus make inapplicable prices useful. *Social Cognition*, 23, 324-335.
- Takemura, K. (1994). Influence of elaboration of the framing of decision. *The Journal of Psychology*, 128, 33-39.
- Von Neumann, J., and Morgenstern, O. (1947). *Theory of Games and Economic Behavior*. Princeton, New Jersey: Princeton University Press.
- Zhang, Y., and Buda, R. (1999). Moderating effects of need for cognition on responses to positively versus negatively framed advertising messages. *Journal of Advertising*, 28, 1-15.

Chapter 21

THE COGNITIVE EFFECTS OF ANXIETY ON SEXUAL AROUSAL

Philippe Kempeneers^{1,2}, Romain Pallincourt² and Sylvie Blairy³

¹University of Liege, Unit of Clinical Psychology, Belgium

²Alexians' Psychiatric Hospital, Henri-Chapelle, Belgium

³University of Liege, Unit of Cognitive-Behavioural Clinical Psychology, Belgium

ABSTRACT

Anxiety and sexual arousal have often been considered as incompatible. Since the end of the 20th Century, however, researches have impaired theories centred on the inhibitory effect of the stress and on peripheral explanations; they rather focus attention on the complexity of the relations between the two states and on cognitive mechanisms.

Now sexual arousal tends to be regarded as a complex response that requires the convergent interpretation of internal and external stimuli. Anxiety may have different effects on this process, sometimes neutral, sometimes facilitating and sometimes inhibitory.

On the one hand, anxiety can trigger a vegetative emotional reaction that may be associated to a concomitant erotic stimulation. Thus, anxiety facilitates the sexual response: this can be called a *priming effect*. This effect is regularly observed in labs, mainly among women. It likely also works in certain compulsive sexual behaviours or, more commonly, in those numerous persons that report being sexually aroused when stressed.

On the other hand, anxiety can cause a massive irruption of non erotic cues in working memory. Therefore, cognitive function available for treating erotic stimuli is diminished and sexual response is impaired. This is an effect of *cognitive interference*. A trait called *erotophobia* could be regarded as a vulnerability factor to cognitive interference. Erotophobic subjects are characterized by a trend to focus upon danger-related information when they are in a sexual situation and by a higher risk of sexual dysfunction.

Anxiety is a recognised etiological factor in the domain of sexual dysfunctions. Previous researches have reported reduced sexual responses in individual suffering from anxiety

(Bodinger et al., 2002; Leiblum et al., 2007; Meana & Nunnick, 2006; Purdon & Holdaway, 2006; Rellini, 2008.) Whether this is caused by concerns regarding self-image, one's physical appearance, one's performance as a lover or the fear of getting pregnant, or fears of being abandoned or worries relating to everyday difficulties, or whether it is the result of a social phobia, a panic disorder or a history of sexual abuse, all the observations converge towards one point: anxiety and sexual stimulation are not a good match.

Among clinicians, it was widely believed, for a long time, that anxiety was an antagonistic state of sexual responses. Many authors have theorised on this issue. The most well known, Masters and Johnson (1970) described the now famous performance anxiety mechanism: worried about their sexual performance, dysfunctional patients cannot indulge in pleasure; they behave like a worried spectator, concerned about their own performance, thus managing to inhibit the sexual responses for which they are hoping and praying. This form of vicious circle was presented as the primary cause of chronic sexual dysfunction. In 1974, Kaplan pointed out that other causal factors were sometimes added to the anxiety of performance, which were more deeply rooted in the history of the subject but also related to anxiety: the fear of intimacy, for instance, the feeling of guilt associated with sexuality or the fear of being abandoned. The fact is that up until quite recently, clinicians tended to represent anxiety and sexual arousal as irreconcilable states. They were more or less explicitly inspired by the works of Wolpe (1958) on reciprocal inhibition. The principle of reciprocal inhibition postulated an incompatibility between certain neurovegetative states. Specifically, anxiety, a state where the activity of the sympathetic system predominates, was considered to be incompatible with sexual arousal, whose initiation requires parasympathetic activity. According to Wolpe (1958), anxiety and arousal states are mutually exclusive. Wolpe's theory attributes the inhibitory effect of one state upon the other to a direct physiological causality effect.

In the beginning, the theory of reciprocal inhibition was very appealing to clinicians sensitive to the almost constant presence of elements of anxiety implicit in functional problems. However, beyond the field of sexual dysfunctions, various elements caused doubt regarding such a simple and direct inhibitory relationship. First, several anecdotes evoked the possibility of sexual arousal stimulated by stress. For examples, stories of lovers who were stimulated by the fear of being caught in the act, stories of couples where sexual relations following a "good old" argument were all the more intense, or stories of rape carried out in the heat of anger. Clinical observations then became systematic. Since the work of Marshall, Laws & Barbaree (1990), we now know that certain types of criminal sexual behaviour are stimulated by stress or are the result of humiliation. It is also the case for certain cases of paraphilia and for compulsive sexual behaviour where stress is often a trigger (Bancroft & Vukadinovic, 2004; Kafka, 2007). Moreover, surveys carried out among the general population also showed that anxiety and arousal can sometimes go hand in hand. For instance, the survey published in 2003 by the Bancroft team showed that 28.3 % of the interviewed men have reported that anxiety put a strain on their sexual interests, while 20.6 % considered it to be stimulating. Twenty percent is fairly significant. It is highly unlikely that we are only dealing with marginal cases of compulsive or deviant sexuality. The survey by Lykins, Janssen and Graham carried out in 2006 on female students also showed similar results. In this survey, 10 % of the students reported to be sexually stimulated by anxiety. Clearly, anxiety is not only an antagonist of sexual functioning; it can also, and quite often, be an agonist. This rapidly led to the belief that anxiety-arousal relations were probably more

complex than the reciprocal inhibition theory suggested. During the last two decades, we have gone from a theory centred on inhibition and the peripheral physiological mechanisms to a theory insisting more on the complexity of the relations between the two states and on the cognitive explicators.

THE CONTRIBUTION OF PLETHYSMOGRAPHY

As mentioned above, the observations made outside the field of sexual dysfunctions have cast doubt on the theory of reciprocal inhibition. Consequently, numerous studies have investigated the understanding of anxiety-arousal relations. In this context, the plethysmographic techniques were often employed. Plethysmography allows sexual arousal to be assessed in a subject by providing a direct description of the person's state. The level of arousal is inferred from genital vasocongestion. In men, a sensor ring is fitted around the penis; it is sensitive to variations in pressure, thus allowing the tumescence of the organ to be measured. This is what is known as *penile plethysmography*. In women, a vaginal probe sensitive to colour variations in the wall of the vagina allows the extent of the blood flow in this area to be determined. This is *vaginal photoplethysmography*. The measurements generally take place when the subject is exposed to erotic stimuli, either audio (recorded material) or video (explicit films).

Initial Experiments

The first experimental arguments against the theory of reciprocal inhibition were put forward by Hoon, Wincze and Hoon in 1977 on female subjects, and by Wolchik et al. in 1980 on male subjects. They were reproduced in 1990 by Palace and Gorzalka on a sample of women. In these experiments, before viewing erotic images, half the subjects were exposed to an emotional film that induces anxiety (accident scenes), and the other half of subjects were exposed to an emotionally neutral film (the control condition.) The participants' sexual arousal was measured. The result showed that sexual arousal among participants firstly exposed to anxiogenic stimulus was not inhibited compared to participants firstly exposed to a neutral film. On the contrary, in the studies by Hoon et al. and Palace and Gorzalka, the initial exposure to an anxiogenic stimulus even seemed to facilitate arousal. Such results did not support the idea of an incompatibility between anxiety and arousal states. The observed priming effect of the one on the other observed in women even tended to support the opposite theory of psychophysiological processes common to both states.

Sympathetic Activity

Sympathetic activity was considered by Wolpe as the physiological foundation of the anxious inhibition of sexual reactivity. The experiments of Hoon et al. and Wolchik et al. did not completely invalidate this mode of action. Indeed, it was possible that the so-called anxiogenic stimuli did not provoke a sufficiently intense sympathetic reaction to exercise an

inhibitory effect on arousal. However, Lange et al. (1981) and Meston and Heiman (1998) had directly stimulated the sympathetic system using chemicals. Lange and his team injected male subjects with effective doses of epinephrine, a sympathicomimetic substance, just before being exposed to erotic films. They compared their sexual arousal with subjects receiving an injection of a placebo. No difference emerged. Their results were in line with the results of Wolchik's previous studies (1980). Meston and Heiman (1998), administered ephedrine, another sympathicomimetic substance to female subjects and reported a slight increase of arousal compared to the placebo group. Here, the results were the same as those of the initial experiment by Hoon et al. (1977). Similar results were also obtained by Meston and Gorzalka (1995, 1996) where the sympathetic activity of female subjects was induced through physical exercise. In conclusion, it appears that anxiety and the accompanying sympathetic activity are perfectly reconcilable with sexual arousal; they may even slightly encourage it: this is far from the principle of reciprocal inhibition.

Experimental Reproduction of Performance Anxiety

Wolpe's theory is clearly not the most pertinent theory to explain the links between anxiety and arousal. However, anxiety is definitely almost a constant in clinical dysfunctional tables. Therefore, it is possible that sexual anxiety has particularities that distinguish it from other negative emotions. The inhibition of arousal could be the result of perceptual and cognitive components specific to performance anxiety. Masters and Johnson, who considered performance anxiety to be the main factor responsible for arousal problems, insisted on the specific attitude caused by this type of fear: the patients became *spectators* of their own performance rather than the *actors*. Isn't it this particular mental state that characterises sexual anxiety and renders it incompatible with sexual arousal?

In order to test this hypothesis of a specificity of performance anxiety, Barlow, Sakheim and Beck attempted to reproduce the appearance conditions in an experiment in 1983. They measured arousal in male subjects who were given erotic films to watch after they had been threatened with electric shocks if their erectile performance did not reach an acceptable level. Arousal in these subjects, who were supposedly made anxious regarding their sexual performance, was compared to the arousal of subjects, on the one hand, who were also threatened with shocks but not in relation to their erectile performance, and, on the other hand, to subjects who had not been threatened. The purpose of the study was to compare the respective impact of performance anxiety (first condition), anxiety not linked to performance (second condition) and the absence of anxiety (third condition). The results were completely opposite to what the clinical considerations of Masters and Johnson predicted. Not only was sexual arousal greater in the threatened subjects compared with those who had not been threatened but, what's more, sexual arousal in the subjects threatened in relation to their erectile performance was even greater than in the subjects who were threatened, though not in relation to their sexual responses.

In 1990, Hale and Strassberg operationalized performance anxiety in a slightly different way. Male subjects were exposed to erotic stimuli. The sexual anxiety was provoked by somewhat hurtful intervention of an experimenter after an initial phase of plethysmographic measurements: when the experimenter examined the first set of results, he pretended to be disappointed that the level of erection achieved was lower than normal. The experiment then

continued and the arousal obtained during the second phase of the experiment by the supposedly disconcerted subjects with respect to their sexual performance, was compared with the control subjects; on the one hand, the subjects who were made anxious without any link to erectile performance (threat of electric shocks independent of the levels of erection) and, on the other hand, subjects who were not made anxious. Contrary to Barlow et al., (1983) Hale and Strassberg (1990) observed an inhibiting effect on sexual arousal caused by stress. However, the mode of anxiety induction had no specific effect: the subjects who were made anxious in relation to their erectile performance or in relation to the possibility of an electric shock showed equivalent levels of arousal, in both cases lower than the control subjects who suffered no pressure or threats.

In 1997, Elliot and O'Donohue carried out a similar experiment with women. Performance anxiety was induced by making the subjects believe that the experimental session would be filmed on video. Research assistants would watch the recordings later and assess the subjects according to levels of "attraction", "personality" and "body language". This procedure did not provoke any significant reduction in sexual arousal: it remained equivalent to that of the control subjects.

In conclusion, the results from these three experiments do not support the hypothesis of a particularity of performance anxiety that endows it with an actual inhibitory effect on sexual arousal.

The Exception of Dysfunctional Subjects

In experimental conditions, anxiety does not appear as a typically inhibitor variable of sexual responses. Further, the links to performance changes nothing. In most plethysmographic studies, it has no impact on arousal, in fact, if anything, it encourages it (Barlow, Sakheim & Beck, 1983; Elliot & O'Donohue, 1997; Hoon, Wincze & Hoon, 1977; Lange et al., 1981; Meston & Gorzalka, 1996; Meston & Heiman, 1998; Palace & Gorzalka, 1990; Wolchik et al., 1980). It is only in Hale and Strassberg's study (1990) that it seemed to act against arousal. However, clinicians tended massively to consider anxiety as one of the major causes of sexual dysfunction. Were clinical intuitions really so wrong? Or maybe the inhibitory effect of anxiety is due to particularities present in clinical subjects and not in experimental subjects?

The results from an experiment conducted in 1987 by Beck, Barlow, Sakheim and Abrahamson on clinical subjects support this hypothesis. The authors have employed the paradigm of the threat of shocks used by Barlow et al. in 1983. They compared plethysmographic measurements taken on men with non-organic erectile problems with those from men with no history in erectile dysfunction. Like Barlow et al. in 1983, they noticed that anxiety induced by the threat of shocks in non-clinical subjects had no effect at all or even slightly facilitated arousal; however, in dysfunctional subjects, it clearly had an inhibitory effect.

The results from Palace and Gorzalka (1990, *op. cit.*) and Meston and Gorzalka (1996, *op. cit.*) also support the theory of a different response to anxiety in dysfunctional subjects. The priming effect of anxiety on arousal observed in non-clinical female subjects was not observed as clearly in women suffering from a functional orgasm disorder.

Overall, these results corroborate the clinical point of view of anxiety being responsible for sexual dysfunctions: anxiety can well and truly have an antagonistic effect on sexual responses; only, the anxiety-arousal relationship is not as simple and linear as initially suggested. To be specific, the inhibitory effect of anxiety probably requires the intervention of a third-party mechanism. If this mechanism is absent, as would be the case in most non-clinical subjects in the plethysmographic experiments, then anxiety has no impact on arousal, or even potentialises it, and if it is present, which would be the case in dysfunctional patients, then anxiety inhibits arousal. This raises the following question: what is the third-party mechanism without which anxiety does not inhibit anything?

Cognitive Interference

Several studies converge towards designating *distraction* as an agent that is directly responsible for the inhibition of sexual responses.

In 1976, Geer and Fuhr had shown that arousal in male subjects exposed to erotic recordings diminished when they were subjected to distracting auditory stimuli at the same time. In 1979, an experiment by Farkas, Sine and Evans led to the same observation. In 1985, Adams, Haynes and Brayer showed that the same was true in female subjects.

Based on a literature review carried out by Barlow's team between 1985 and 1994, Sbrocco and Barlow (1996) concluded that distraction brought non-clinical subjects down to the same level of sexual arousal as clinical subjects affected by anxiety, the idea being that the latter were already distracted by their anxious preoccupations alone. All in all, what distinguishes functional and dysfunctional subjects for Sbrocco and Barlow, is neither the presence of anxiety nor its intensity, or even the fact that it is related to performance – this seems commonly experienced by non-clinical subjects without this disrupting their sexual responses – but the fact that it has this particular power in dysfunctional subjects to divert their attention towards non-erotic considerations (e.g. a negative self-image, their partner's disappointment). The cause of sexual dysfunctions is now conceived in terms of cognitive interference. From this point of view, anxiety indirectly explains functional problems: it encourages interference, i.e. it diverts the attention from erotic stimuli to non-erotic stimuli, but it is neither a sufficient nor necessary condition to inhibit arousal. It is insufficient because anxiety cannot interfere with the attention dedicated to the erotic situation; in this case, it has no effect, and it is not necessary because stimuli and thoughts other than anxiogenic can also create an interference, mobilising attention to the detriment of the erotic situation.

The inhibitory role of cognitive interference was again confirmed by Elliot and O'Donohue (1997, op. cit.). As mentioned above, the anxiety induced in this study on female subjects had no influence on their arousal. However, the experiment also had a second aim which was to assess the effect of distracting stimuli. While viewing erotic recordings, some subjects had to listen to sentences and repeat them according to more or less simple or complex instructions. Here, the effect was clearly significant: the inhibition of arousal was directly proportional to the level of distraction.

Contrary to distraction, anxiety has therefore no specific inhibitory effect. When anxious subjects have a reduced level of arousal, anxiety has obviously provoked the diversion of their attention from the erotic situation. This cognitive way of thinking also provides elements

that explain the atypical results of Hale and Strassberg's study (1990, op. cit.), one of few to have found that anxiety induced through experimental manipulation gave rise to a reduction in sexual responses (see above). When questioned about the thoughts they had during the experiment, the stressed subjects' answers were quite distinct from those of the control subjects owing to the higher number of non-erotic preoccupations that had attracted their attention (i.e. "Why didn't I get an erection?", "Will the electric shock hurt me?")

Finally, in 2001, Koukounas and McCabe observed that sexual arousal in male subjects exposed to erotic films strongly correlated with the impression they said they had of their attention being fully absorbed by the film.

Finally, these studies have led to a better understanding of the nature of the anxious inhibition of sexual responses. We now think that cognitive interference is the true *modus operandi*.

TOWARDS A COGNITIVE THEORY OF THE AROUSAL-ANXIETY RELATIONSHIP

It is now clear that anxiety can have various influences on arousal: it can have an inhibitory effect, via the *interference effect*, or play the role of facilitator, known here as the *priming effect*. Besides the studies that relate directly to sexual arousal, an additional series of work and concepts have enabled us to specify the possible nature of cognitive mechanisms involved in priming and interference effects. A cognitive theory of the arousal-anxiety relationship has begun to take shape.

The Priming Effect

Plethysmographic studies have not merely shown that, in the absence of the interference vector, anxiety and arousal remain perfectly compatible, they have also shown that the first could even have an agonistic effect on the second. The increase in sexual reactivity observed in subjects exposed to experimental conditions (Barlow et al., 1983; Hoon et al., 1977; Meston & Gorzalka, 1995, 1996; Meston & Heiman, 1998; Palace & Gorzalka, 1990) effectively provides objective support for the feeling reported by numerous people that stress in fact favours arousal. All that remains is to explain this effect. Various models elaborated in the domain of the psychology of emotion help to elucidate the issue.

It is now established that the production of emotions is a process comprised of several stages (Damasio, 2003; LeDoux, 1996). Firstly, a rapid and mostly unconscious analysis of the trigger situation is made. The operation mainly takes place in the amygdale; this is at the origin of a somewhat undifferentiated primary physiological reaction, essentially comprised of vagal modifications. Secondly, cortical connections come into play and determine a secondary processing of the stimuli during which the emotion is adjusted, specified and led to consciousness. At this stage, the information from the environment (signs of danger for instance, or indications of a pleasant event) will direct the interpretation of the experience, giving it a particular affective character (sometimes worrying, sometimes exciting). At the same time, the information concerning the internal state (primary vagal modifications)

confirms the emotional nature of the situation: "I can feel that it is affecting me". Thus, through an interactive process, the particular physiological and subjective characteristics of the emotion are revealed. The same is probably true for sexual arousal: internal feelings and the erotic stimuli mutually guide each other to create a specifically erotic emotion.

In numerous situations of everyday life, we can observe a coupling mechanism between the characteristics of the trigger stimulus and the primary physiological reaction. External and internal stimuli in some way mutually confirm each other, leading to the emotional experience. During this process, biases can however occur: the coupling normally expected between the primary physiological reaction and the characteristics of the trigger situation can indeed be altered by the intrusion of information that is foreign to the initial conditions. Thus, unexpected emotions are produced. Two experiments illustrate this bias in the sexual domain; their results showed that the sexual emotion can be caused by elements that are completely foreign to erotic stimuli. As such, they give us an idea of the mechanisms that probably contribute to the element that prime arousal through anxiety.

1. Valins (1972) reports having exposed male subjects to erotic slides. During this time, a device measured their heart rate and they were made to listen to the sound of their own heartbeat. At least that is what they thought because, in reality, the heartbeats they heard were manipulated by an experimenter who made the rhythm vary at random, increasing it when certain images were shown and reducing it for others. When they were asked to point out the photos they liked the most, the subjects showed a tendency to select those that were associated with a pseudo-modification of their heartbeat.
2. In an experiment conducted in 1974 by Dutton & Aron, male subjects had to cross a footbridge that overlooked a canyon. Straight after this stressful ordeal, an interview took place with a female researcher. During the interview, the researcher asked the subjects to make up a story based on the drawing of a woman, then, when they had to leave, she gave them her card. Compared with subjects who had the same interview with the same researcher, though without having had to cross the harrowing footbridge beforehand, a significantly higher number of the stressed subjects made up stories with a sexual content and contacted the researcher afterwards in the hope of seeing her again.

These two experiments showed that the sexual emotion may be encouraged by the perception of a physiological activation whose origin is absolutely not erotic. Produced through arbitrary manipulation by Valins or through a sensation of fear by Dutton and Aron, the perceived physiological activation is coupled with a sexual stimulus that is foreign to its cause but concomitant in such a way that the emotion develops or reinforces itself in a sexual direction. This mechanism probably also plays a role in the priming elements revealed by the plethysmographic studies: the physiological activation induced by stress is attributed to an erotic source, with the result of encouraging the emotion and sexual responses.

Sexual arousal is an experience that results from the converging interpretation, in an erotic sense, of a series of signals from both the internal and external environment. To be exact, it should be noted that the genital vasocongestion reaction does not signal the end of the arousal process. It is merely a stage in a process that is only finally expressed with the subjective sensation of arousal. The reader will undoubtedly have noticed that, without it

being their exclusive privilege, the priming effect seems to be more widespread among women. At the same time, the genital reaction measured by plethysmography in women is not necessarily accompanied by a conscious impression of arousal. In men, on the other hand, there are quite good correlations between plethysmographic measurements and subjective feeling of arousal. This inter-gender difference can undoubtedly be explained through the more external location of the male genital organs: this anatomical data means that in comparison to women, men have a greater number of perceptive retroactive channels; the physiological signs of their arousal are more accessible via the visual channel and tactile sensations, which all allow a closer adjustment of genital and subjective responses. Probably as a result of this, genital vasocongestion in women appears to be a less specific response of arousal, less differentiated or less accomplished than it is in men (Chivers, 2005). Regardless of gender difference, the relative imbalance between the genital response and the subjective feeling bears witness to the sequential nature of the sexual arousal process. From the primary physiological response to the subjective experience, arousal is an experience that occurs progressively, during cognitive processes of increasing complexity and through certain hazards such as possible attribution biases.

The Effect of Interference

Anxiogenic stimuli are not always interpreted in a pro-erotic sense. The priming effect of arousal through anxiety is not an absolute. It clearly is not the case in numerous individuals suffering from a functional arousal or orgasm disorder. For these people, sexual inhibition based on anxiety remains a tiresome reality. However, the explanation of the phenomenon no longer refers to an improbable physiological incompatibility of the two states but rather cognitive interference.

In individuals suffering from sexual dysfunction, the anxiety that occurs in a sexual situation seems to act as a source of distraction; it triggers an intense cognitive activity, focused on danger, which interferes with the processing of erotic stimuli. Typical sexual anxious preoccupations – “Is it going to work?”, “What does my partner think of me?” – or even everyday concerns, sometimes have this ability to overwhelmingly monopolise the subject’s attention, to the point where the remaining resources are insufficient to ensure the normal execution of a sexual response. Therefore, it is not stress in itself that is the efficient inhibitory factor but the degree of distraction that it causes in certain people.

Erotophobia and Emotional Stroop

Not everyone is as vulnerable to the effects of anxious interference. People who risk suffering from sexual dysfunction seem to have a particular profile that Byrne and Schutle (1990), and later Sbrocco and Barlow (1996), qualified as *erotophobia*. Erotophobia consists of a tendency to associate sexuality with ideas of danger. There is a cognitive and emotional structure similar to the one that can be found in numerous anxiety disorders, though in this case, the object is sexuality. Therefore, it is a *phobia* linked to sexuality.

It has now been demonstrated that, in anxious individuals, the cognitive processing of a stimulus in relation to their emotional difficulties is far more costly in terms of attention than

the processing of the same stimulus in a person who is not anxious. This phenomenon was objectivised using a variant of the Stroop test called *emotional Stroop*. Through the Stroop test, it is possible to measure the interference of one cognitive activity over another. In its classic form, the test consists of presenting the subject with a series of written words using different coloured ink; the person is instructed to name the colours of the inks used and not to read the words. The examiner takes note of how quickly the instruction is obeyed to name the colours, knowing that this speed depends on the ease with which the subject manages to inhibit the execution of an interfering activity, i.e. an automatic tendency to read the words presented. The effect of interference of reading over naming the colours is measured here in time units: the greater it is, the more time will be required to execute the instruction. Reading has become automatic in almost every literate person who is exposed to written words, and it is this automatic behaviour which, in the Stroop test, creates an activity that is capable of interfering with another, less banal activity, such as naming font colours. As regards the emotional Stroop, it introduces an additional variable, the affective connotation of the words given to read. This Stroop variant shows that the effect of interference also depends on the emotion – anxiety in particular – caused by the stimulus. For instance, in anxious people suffering from social phobias, that is who are anxious in social relations, concerned about rejection, they need more time to name the colour of ink that is used to write a critical word such as “humiliation”, than to name the colour of an affectively neutral word such as “geology”. However, this difference in reaction time is not found in people who do not suffer from a social phobia (Mattia, Heimberg & Hope, 1993). In the same way, there are longer reaction times in people with arachnophobia, with words such as “spider” or “web” (Lavy, Van den Hout & Arntz, 1993); or with words such as “suffocate” in people who suffer from panic disorder (McNally, Riemann & Kim, 1990); with words relating to a trauma experienced by the subject (e.g. “rape”, “Vietnam”) in the case of post-traumatic stress disorders (Kapsi, McNally & Amir, 1995; McNally, English & Lipke, 1993); and with words such as “accident” in people suffering from generalised anxiety (Martin, Horder & Jones, 1992). In anxious people, the reaction times are systematically longer for words that evoke their specific anxious concerns. The effect of interference due to the emotional load of the stimulus leads us to believe that in people who are sensitive to it, some specific themes provoke an automatic cognitive activity centred on the notion of danger. Absorbing a significant amount of the subject’s mental resources, this activity hinders the achievement of another task.

To our knowledge, erotophobic subjects have never been assessed using emotional Stroop-type tests, which would target words that evoke sexual situations. However, it would not seem to be excessively rash to suppose that the same would be true for these people as for other anxious subjects. Therefore, Kempeneers and Barbier (2008) suggest considering erotophobia as a factor of cognitive interference. In a sexual situation, erotophobic subjects would tend to develop a cognitive activity focused on the notion of danger. Encroaching upon the resources allocated to the processing of the situation’s erotic components, this activity would lead to an increased risk of sexual dysfunction in these subjects.

The Working Memory

The inhibitive power of distraction leads us to consider that these people are endowed with a limited ability to process information. Above a certain quantitative threshold, the

cognitive resources required to process a second supposedly distracting stimulus (i.e. non erotic) must be taken from those allocated to the processing of a primary stimulus (i.e. erotic). The concept of *working memory* seems to be adapted to the description of the process. According to Eyzenck (1991) and Peretti & Ferreri (2004), in people suffering from chronic anxiety who are confronted with sensitive themes, it is as though the working memory is saturated by information relating to the management of a source of danger, to the point where the execution of other tasks is altered. The working memory is a concept that was proposed and developed by Baddeley (Baddeley, 1992; Baddeley & Hitch, 1974). On a schematic level, it can be compared with the random access memory of a computer. It is the functional entity that allows you to momentarily keep in mind elements of information that are useful to accomplish a task. These elements are taken from the external environment on the one hand – an erotic stimulus for instance – and from the internal environment on the other hand – memories of similar experiences, schemas of actions learnt, moral values evoked by the situation, etc. Contrary to other forms of memory allocated to storing information in the long term, the working memory functions in a transitory way. The information only spontaneously remains for a few seconds. This goes hand in hand with its limited availability: the mass influx of new information tends to suppress those relating to the tasks in hand. In the terms of this model, anxiety provokes a saturation of the working memory in erotophobic subjects to the detriment of the resources essential to the execution of sexual responses. Elements of information relating to the management of danger come to the fore and compete with the erotic information.

The Attentional Benefit of Anxiety

The work of Mandler (1984) on the attentional effects of emotions is also of interest. According to Mandler, stress always has the effect of increasing vigilance. This explains why anxiety can sometimes facilitate the execution of certain tasks. In 1908, Yerkes & Dodson had pinned down the non-linear character of the relationship between stress and the level of performance to tasks requiring attentional functions: stress was sometimes detrimental to performance, and sometimes it improved it. It seemed to the authors that the optimal level of performance resulted from moderate stress rather than the absence of stress, and that a level of stress that was too high tended to exert a detrimental effect on performance. In reality, Mandler specified in 1984 that the intensity of the emotion is probably not the decisive variable concerning the evolution of the performance; instead, it is the element on which the increased attention provoked by the stress is focused. If it is focused on the elements relating to the task in hand, it logically produces an increase in the level of performance. If, on the contrary, it is focused on elements that are external to the accomplishment of the task, then the subject is distracted and his/her performance is poorer. It is easy to transpose Mandler's model to the area of sexual performance. When anxiety suddenly appears in a sexual situation, there are two possible scenarios:

1. The majority of the subject's attention may be drawn to elements of danger that are foreign to the erotic task in hand. His/her working memory is saturated with information of a non-erotic nature resulting in a reduction in sexual performance.

This is a case of the interference effect which can be found in stressed erotophobic subjects in a sexual situation.

2. In the absence of such a mechanism that shifts the cognitive resources, attention is maintained on the information of an erotic nature. This information thus benefits from a positive attentional balance that can result in an improvement in sexual performance. Under these conditions, a priming effect is obtained. This tendency would be more likely to occur in non-erotophobic subjects.

It should be noted that the model elaborated based on the work of Mandler is situated at the opposite end of the scale to Wolpe's. While the latter considered anxiety and arousal to be natural antagonists, the former tends to consider them as naturally agonistic.

CONCLUSION

While anxiety can inhibit sexual responses, plethysmographic studies have shown that this is not always the case. According to the circumstances, anxiety sometimes hinders arousal and sometimes facilitates it. The anxiety-arousal relationship turns out to be more complex than Wolpe (1958), Masters & Johnson (1970) and Kaplan (1974) originally imagined; they considered these states as incompatible.

Finally, the decisive factor of sexual inhibition would appear to be cognitive interference, distraction. It is only when anxiety causes a distraction from erotic stimuli that it may be considered responsible for sexual inhibition. This is not the case for everybody; some people are more prone than others and this tendency seems to be a characteristic of people with a history of non-organic sexual dysfunction. Otherwise, anxiety does not have an impact on levels of arousal; in fact, it improves it.

The results from studies using the plethysmographic tests seem to be linked to studies carried out in related domains. Subject to empirical confirmation, we can therefore suggest the following cognitive theory concerning the relations between anxiety and arousal: sexual arousal can be regarded as a complex response that requires the convergent interpretation of internal and external stimuli. Anxiety may have different effects on this process, sometimes neutral, sometimes facilitating and sometimes inhibitory.

On the one hand, anxiety can trigger a vegetative emotional reaction that may be associated to a concomitant erotic stimulation. Thus, anxiety facilitates the sexual response: this can be called a *priming effect*. This effect is regularly observed in labs, mainly among women. It likely also works in certain compulsive sexual behaviours or, more commonly, in those numerous persons that report being sexually aroused when stressed.

On the other hand, anxiety can cause a massive irruption of non erotic cues in working memory. Therefore, cognitive function available for treating erotic stimuli is diminished and sexual response is impaired. This is an effect of *cognitive interference*. A trait called *erotophobia* could be regarded as a vulnerability factor to cognitive interference. Erotophobic subjects are characterized by a trend to focus upon danger-related information when they are in a sexual situation and by a higher risk of sexual dysfunction.

Finally, anxiety often increases vigilance. The increase in attention thus obtained may focus on erotic stimuli, therefore reinforcing the priming effect. At the opposite end of the

scale, the gain in attention may also be dedicated to danger signals of no erotic value; under these conditions, it is the interference effect which is reinforced.

REFERENCES

- Adams, A.E., Haynes, S.N. & Brayer, M.A. (1985). Cognitive distraction in female sexual arousal. *Psychophysiology*, 22, 689-696.
- Baddeley, A.D. (1992). Working memory. *Science*, 255, 556-559.
- Baddeley, A.D. & Hitch, G.J. (1974). Working memory. In G.H. Bower (Ed.), *The psychology of learning and motivation*, Vol. 8. New York: Academic Press.
- Bancroft, J., Janssen, E., Strong, D., Carnes, L., Vukadinovic, Z & Long, J.S. (2003). The relation between mood and sexuality in heterosexual men. *Archives of Sexual Behavior*, 32, 3, 217-230.
- Bancroft, J. & Vukadinovic, Z. (2004). Sexual addiction, sexual compulsivity, sexual impulsivity or what? Toward a theoretical model. *Journal of Sex Research*, 41, 3, 225-234.
- Barlow, D.H., Sakheim, D. & Beck, J.G. (1983). Anxiety increases sexual arousal. *Journal of Abnormal Psychology*, 92, 49-54.
- Beck, J.G., Barlow, D.H., Sakheim, D.K. & Abrahamson, D.H. (1987). Shock threat and sexual arousal: The role of selective attention, thought content, and affective states. *Psychophysiology*, 24, 165-172.
- Bodinger, L., Hermesh, H., Aizenberg, D., Valevski, A., Marom, S., Shiloh, R., Gothelf, D., Zemishlany, Z & Weizman, A. (2002). Sexual function and behaviour in social phobia. *Journal of Clinical Psychiatry*, 63, 10, 874-879.
- Byrne, D. & Schutle, L. (1990). Personality dispositions as mediators of sexual responses. In J. Bancroft, C.M. Davis & D. Weinstein (Eds.), *Annual review of sex research*. Lake Mills, IA: The Society for Scientific Study of Sex.
- Chivers, M.L. (2005). A brief review and discussion of sex differences in the specificity of sexual arousal. *Sexual and Relationship Therapy*, 20, 4, 377-390.
- Damasio, A. (2003). *Looking for Spinoza: Joy, sorrow and the feeling brain*. Harcourt, Inc.
- Dutton, D.G. & Aron, A.P. (1974). Some evidence for heightened sexual attraction under conditions of high anxiety. *Journal of Personality and Social Psychology*, 30, 510-517.
- Elliot, A.N. & O'Donohue, W.T. (1997). The effects of anxiety and distraction on sexual arousal in nonclinical sample of heterosexual women. *Archives of Sexual Behavior*, 26, 6, 607-624.
- Eyzenck, M.W. (1991). Cognitive factors in clinical anxiety: potential relevance to therapy. In M. Briley & S.E. File (Eds.), *New concepts in anxiety*. London: Mac Millan Press.
- Farkas, G.M., Sine, L.F. & Evans, I.M. (1979). The effects of distraction, performance demand, stimulus explicitness and personality on objective and subjective measures of male sexual arousal. *Behaviour Research and Therapy*, 17, 25-32.
- Geer, J.H. & Fuhr, R. (1976). Cognitive factors in sexual arousal: The role of distraction. *Journal of Consulting and Clinical Psychology*, 44, 2, 238-243.
- Hale, V.E. & Strassberg, D.S. (1990). The role of anxiety on sexual arousal. *Archives of Sexual Behavior*, 19, 6, 569-581.

- Hoon, P.W., Wincze, J.P. & Hoon, E.F. (1977). A test of reciprocal inhibition: Are anxiety and sexual arousal mutually inhibitory? *Journal of Abnormal Psychology*, 86, 65-74.
- Kafka, M.P. (2007). Paraphilia-related disorders. The evaluation and treatment of nonparaphilic hypersexuality. In S.R. Leiblum (Ed.), *Principles and practice of sex therapy* (4th ed.), New York: Guilford Press.
- Kaplan, H.S. (1974). *The new sex therapy*. New York: Brunner/Mazel.
- Kapsi, S.P., McNally, R.J. & Amir, N. (1995). Cognitive processing of emotional information in posttraumatic stress disorder. *Cognitive Therapy and Research*, 19, 433-444.
- Kempeneers, P. & Barbier, V. (2008). The influence of anxiety on sexual arousal: Towards a cognitive theory [L'influence de l'anxiété sur l'excitation sexuelle : vers une théorie cognitive]. *Sexologies*, 17, 2.
- Koukounas, E. & McCabe, M.P. (2001). Sexual and emotional variables influencing sexual response to erotica: A psychophysiological investigation. *Archives of Sexual Behavior*, 30, 4, 393-408.
- Lange, J.D., Wincze, J.P., Zwick, W., Feldman, S. & Hugues, P. (1981). Effects of demand for performance, self-monitoring of arousal and increased sympathetic nervous system activity on male erectile response. *Archives of Sexual Behavior*, 10, 443-463.
- Lavy, E.H., Van den Hout, M. & Arntz, A. (1993). Attentional bias and spider phobia: conceptual and clinical issues. *Behaviour Research and Therapy*, 31, 17-24.
- LeDoux, J. (1996). *The emotional brain*. New York: Simon & Schuster.
- Leiblum, S., Seehuus, M., Goldmeier, D & Brown, C. (2007). Psychological, medical, and pharmacological correlates of persistent genital arousal disorder. *Journal of Sexual Medicine*, 4, 5, 1358-1366.
- Lykins, A.D., Janssen, E. & Graham, C.A. (2006). The relationship between negative mood and sexuality in heterosexual college women and men. *Journal of Sex Research*, 43, 2, 136-143.
- Mandler, G. (1984). *Mind and body. Psychology of emotion and stress*. New York: Norton and Company.
- Marshall, W.L., Laws, D.R. & Barbaree, H.E. (1990). *Handbook of sexual assault: issues, theories and treatment of the offenders*. New York: Plenum Press.
- Martin, M., Horder, P. & Jones, G.V. (1992). Integral bias in naming phobia-related words. *Cognition and Emotion*, 6, 479-486.
- Masters, W.H. & Johnson, V.E. (1970). *Human sexual inadequacy*. Boston: Little Brown.
- Mattia, J.L., Heimberg, R.G. & Hope, D.H. (1993). The revised Stroop colour-naming task in social phobics. *Behaviour Research and Therapy*, 31, 305-313.
- McNally, R.J., English, G.E. & Lipke, H.J. (1993). Assessment of intrusive cognition in PTSD: use of the modified Stroop paradigm. *Journal of Traumatic Stress*, 6, 33-41.
- McNally, R.J., Riemann, B.C. & Kim, E. (1990). Selective processing of threat cues in panic disorders. *Behaviour and Therapy*, 28, 407-412.
- Meana, M. & Nunnick, S.E. (2006). Gender differences in the content of cognitive distraction during sex. *Journal of Sex Research*, 43,1, 56-67.
- Meston, C.M. & Gorzalka, B.B. (1995). The effect of sympathetic activation following acute exercise on physiological and subjective arousal in women. *Behaviour Research and Therapy*, 33, 651-664.

- Meston, C.M. & Gorzalka, B.B. (1996). The effects of immediate, delayed, and residual sympathetic activation on sexual arousal in women. *Behaviour Research and Therapy*, 34, 143-148.
- Meston, C.M. & Heiman, J.R. (1998). Ephedrine-activated physiological sexual arousal in women. *Archives of General Psychiatry*, 55, 652-656.
- Palace, E.M. & Gorzalka, B.B. (1990). The enhancing effects of anxiety on arousal in sexually dysfunctional and functional women. *Journal of Abnormal Psychology*, 99, 403-411.
- Peretti, C.S. & Ferreri, F. (2004). Anxiété et troubles cognitifs. In M. Ferreri (Ed.), *Anxiété, anxiolytiques et troubles cognitifs*. Paris : Elsevier SAS.
- Purdon, C. & Holdaway, L. (2006). Non-erotic thoughts : content and relation to sexual functioning and sexual satisfaction. *Journal of Sex Research*, 43, 2, 154-162.
- Rellini, A. (2008). Review of the empirical evidence for a theoretical model to understand the sexual problems of women with a history of child sexual abuse. *Journal of Sexual Medicine*, 5, 1, 31-46.
- Sbrocco, T. & Barlow, D.H. (1996). Conceptualizing the cognitive component of sexual arousal: Implications for sexuality research and treatment. In P.M. Salkovskis (Ed.), *Frontiers of cognitive therapy*. New York: Guilford Press.
- Valins, S. (1972). Persistent affects of information about internal reactions: Ineffectiveness of debriefing. In R.H. London & R.E. Nisbett (Eds.), *The cognitive alteration of feeling states*, Chicago: Aldine.
- Wolchik, S.A., Beggs, V., Wincze, J.P., Sakheim, D.K., Barlow, D.H. & Mavissakalian, M. (1980). The effects of emotional arousal on subsequent sexual arousal in men. *Journal of Abnormal Psychology*, 89, 595-598.
- Wolpe, J. (1958). *Psychotherapy by reciprocal inhibition*. Stanford: Stanford University Press.
- Yerkes, R.M. & Dodson, J.D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative and Neurological Psychology*, 18, 459-482.
- .

INDEX

A

- abstraction, 7, 151, 256, 257, 356, 430, 500, 503, 538, 539
- Abstraction, 415
- abuse, 224, 296, 309, 580, 593
- abusive, 468
- AC, 292
- academic, 315, 320
- academics, 377
- acceleration, 101
- access, 53, 68, 93, 94, 104, 125, 134, 136, 140, 141, 144, 155, 283, 305, 329, 343, 345, 417, 427, 504, 532, 589
- access consciousness, 504
- accessibility, 68, 170
- accidents, 385, 388, 459, 471
- acclimatization, 279
- accountability, 348
- accounting, 355, 504, 507
- accuracy, 113, 122, 131, 153, 176, 182, 183, 184, 191, 199, 201, 205, 219, 318, 518, 520, 524
- acetylcholinesterase, 278
- acetylcholinesterase inhibitor, 278
- Ach, 83
- achievement, 51, 182, 267, 304, 315, 568, 588
- ACM, 59
- acquaintance, 286
- acquisition of knowledge, 373
- activation, 18, 42, 70, 110, 132, 151, 154, 166, 190, 222, 302, 308, 309, 427, 461, 462, 506, 539, 540, 547, 552, 561, 565, 571, 575, 576, 577, 586, 592, 593
- activity level, 417
- actuality, 122
- acute, 308, 504, 592
- acute schizophrenia, 504
- AD, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 286, 287, 288
- Adams, 300, 307, 584, 591
- adaptation, 119, 233, 281, 322
- adaptations, xii, 237, 316, 382, 405, 560
- addiction, 31, 183, 307, 591
- adjustment, 230, 237, 303, 571, 587
- administration, 382
- adolescence, 166
- adolescents, 187
- adrenal hyperplasia, 166
- adult, 10, 17, 166, 167, 169, 170, 185, 186, 192, 194, 401, 409, 411, 412, 420, 539
- adulthood, viii, 160, 166, 167, 170, 171, 179, 185
- adults, viii, 42, 83, 133, 151, 155, 156, 159, 164, 168, 169, 170, 171, 177, 178, 179, 180, 181, 182, 183, 184, 185, 190, 191, 379, 382, 406, 408, 418, 419, 420, 461, 530, 565
- advancement, 380, 572
- advancements, 569
- advertising, 577
- aerobic, 284
- aerobic exercise, 284
- aesthetic, 524
- aesthetics, 498
- AF, 8, 9, 11, 13, 16, 33, 36, 289
- affective dimension, 104
- affective states, 307, 591
- affirming, 420
- agent, 6, 29, 30, 31, 35, 37, 44, 45, 46, 47, 71, 75, 86, 90, 300, 398, 584
- AGFI, 390, 391
- aggregation, 222
- aggression, 194, 503
- aggressiveness, 360

-
- aging, 134, 153, 155, 167, 168, 169, 171, 282, 289, 515, 534
- agonist, 296, 555, 580
- aid, 263, 275, 285, 286, 292
- air, 59, 322, 324, 358
- Air Force, 2
- AJ, 290
- AL, 291, 292
- Albert Einstein*, 228
- alcohol, 436, 464
- alcoholics, 464
- alcoholism, 436
- alertness, 99, 100
- algorithm, 79, 360
- ALI, 15
- allele, xiii, 515, 525, 529, 531
- alpha, xi, 76, 115, 213, 320, 376, 379, 382, 397
- alternative, 16, 38, 39, 50, 52, 83, 85, 93, 135, 136, 156, 234, 258, 259, 276, 282, 352, 364, 398, 399, 434, 467, 468, 488, 570, 571
- alternative causes, 398
- alternatives, 237, 355, 401, 454, 469, 548, 571, 572, 574
- alters, 87, 231
- Alzheimer disease, 278, 283, 286, 288, 289, 290, 530, 532, 534
- Alzheimer's, 287, 288, 289, 290, 291, 292, 293
- Alzheimer's disease, 287, 288, 290, 292, 293
- Alzheimer's Disease, 287, 289, 290
- Alzheimer's, 274, 279, 283, 286, 287, 288, 289, 290, 291, 292
- Alzheimer's disease, 279, 283, 287, 288, 289, 290, 291, 292
- AM, 289
- amalgam, 356, 360, 364, 366, 370
- Amalgam, 350, 356, 357, 364, 369
- ambiguity, 36, 38, 111, 202, 371, 399, 472, 577
- American Psychological Association, 373
- amnesia, 155, 533
- amphibia, 491, 493
- amphibians, 497
- amplitude, xiv, 279, 551, 552, 556, 558, 559, 560
- Amsterdam, 59, 62, 242, 374, 427, 430, 463, 563
- amygdala, 517
- AN, 289
- anaesthesia, 97
- analysis of variance, 213, 394, 542, 543, 545, 574
- analysts, 319
- analytical framework, xi, 349, 350, 362, 364, 369, 370, 486
- anatomy, 109, 490
- androgen, 166, 191
- androgens, 166
- anger, 106, 285, 296, 468, 469, 470, 482, 483, 485, 580
- Anglo-Saxon, 313
- animal communication, 25, 53
- animal models, 182
- animals, xiv, 25, 27, 41, 53, 72, 83, 85, 92, 101, 161, 182, 185, 406, 437, 463, 513, 517, 524, 525, 531, 537, 539, 540, 547
- ANOVA, 178, 179, 180, 206, 442, 443, 445, 446, 449, 451
- ANS, 561
- antagonist, 296, 580
- antagonistic, 247, 296, 300, 580, 584
- antagonists, 306, 555, 590
- antecedents, 466, 485, 487, 488
- anthropological, 313, 406
- anthropology, 312, 314, 315
- Anxiety, x, xii, xv, 295, 298, 301, 305, 306, 307, 376, 382, 400, 401, 402, 435, 441, 442, 448, 461, 462, 464, 579, 582, 585, 589, 590, 591
- anxiety disorder, 303, 378, 379, 399, 438, 442, 456, 587
- AP, 290
- apathy, 281, 283, 289
- APOE, xiii, 515, 525, 529
- Apolipoprotein E, 530, 532, 534, 535
- appendix, 319
- apples, 41, 363
- application, 386, 466, 539, 544
- applied mathematics, 314
- appraisals, 399
- aptitude, 161, 189, 192
- Argentina, xiii, 245, 265, 270, 271, 470, 489, 493, 508, 509, 510, 511
- argument, 64, 91, 95, 201, 296, 359, 407, 415, 472, 548, 567, 580
- Aristotelian, 490, 505
- Aristotle, xiii, 489, 504, 510, 512
- arithmetic, 503
- Arkansas, 117
- Army, 114
- arousal ratings, 434
- arthropods, 497
- articulation, 345
- artificial intelligence, 228, 254, 329, 350, 358, 365, 370
- artificial organs, 78
- Asia, 60
- Asian, 165

asparagus, 516
 assault, 131, 308, 592
 assessment, xii, 166, 170, 186, 193, 213, 272, 287,
 290, 335, 380, 401, 402, 433, 440, 441, 442, 455,
 462
 assimilation, 505
 assumptions, 64, 73, 80, 86, 87, 99, 120, 140, 148,
 150, 259, 350, 353, 357, 362, 364, 365, 371, 527
 astronomy, 314, 315
 asymmetry, 419, 463
 Athens, 496, 510
 athletes, 553
 Atlas, 59, 508, 509
 atmosphere, 286
 atomic physics, 315
 atoms, 3, 315
 atrophy, 526, 535
 attention, 280, 282, 284
 attentional bias, 435, 436, 438, 448, 454, 455, 461,
 462, 463
 attentional blink, 93
 attitudes, 2, 38, 82, 84, 168, 187, 193, 270, 456, 457,
 467, 470, 472, 483, 487
 attractiveness, 488
 attribution, 258, 303, 355, 356, 362, 366, 368, 369,
 370, 372, 549, 587
 attribution bias, 303, 587
 atypical, 275
 audition, 232, 234, 503
 auditory stimuli, 77, 234, 300, 584
 authorities, 262
 autism, 425
 autobiographical memory, 152, 199, 222, 282, 289
 automatic processes, 558
 automaticity, 111, 153, 569, 575
 automation, 261
 Automobile, 243, 471
 autonomic nervous system, xiv, 504, 552, 559, 561,
 562, 563, 564, 565
 autonomy, 72, 104, 261
 availability, 144, 148, 150, 257, 263, 305, 455, 504,
 589
 averaging, 160
 aversion, 574
 avian, 493
 avoidance, 435, 436, 437, 444, 453, 454, 455, 456,
 461, 463, 464, 472
 avoidance behavior, 437
 awareness, xii, 69, 84, 88, 89, 90, 91, 92, 93, 94, 95,
 96, 111, 112, 114, 140, 141, 209, 246, 261, 264,
 267, 282, 433, 568, 571, 573

axon, 507
 axonal, 434
 axons, 233

B

Baars, 2, 57, 65, 67, 68, 82, 91, 95, 96, 107, 108
 babies, xii, 284, 405, 407, 410, 412, 418, 419, 428
 back, 6, 10, 37, 75, 106, 135, 149, 205, 229, 236,
 237, 247, 282
 background information, 317
 banking, 466, 468
 barriers, 469, 484, 487
 basal ganglia, 503, 552
 base, 77, 151, 169, 222, 250, 257, 272, 278, 286,
 291, 292, 353, 354, 355, 364, 413, 474, 482, 503,
 516, 525, 540
 basketball, 357
 battery, 80, 97, 101, 186, 273, 379, 381
 BDI, 382, 393, 394, 395, 396
 Beck Depression Inventory, xii, 376, 382, 400, 402
 beer, 436
 behavioral aspects, 279
 behavioral assessment, 462
 behavioral manifestations, 569
 behavioral problems, 230, 275, 280, 292
 Behaviorism, 67
 behaviors, 80, 280, 281, 283, 290, 292, 394, 395,
 396, 398, 407, 409, 468, 488, 503, 505, 569
 behaviours, x, xv, 295, 306, 411, 472, 579, 590
 Belgium, 295, 579
 beliefs, xi, xii, 82, 253, 375, 376, 377, 378, 399, 400,
 401, 403, 456, 457
 beneficial effect, 113
 benefits, 150, 279, 306, 469, 473, 576, 590
 Bible, 497, 510
 biceps brachii, 553
 binding, viii, 66, 106, 114, 117, 119, 120, 121, 122,
 123, 124, 125, 126, 127, 128, 129, 130, 131, 132,
 134, 135, 136, 137, 138, 139, 147, 150, 151, 153,
 155, 156, 322
 binding energy, 322
 biochemical, 289
 biological processes, 97
 biological systems, 101, 103
 bipedal, 406
 birds, 351, 357, 411, 427, 538, 539, 540
 birth, xii, 27, 44, 276, 319, 327, 331, 333, 336, 338,
 405, 406, 407, 410, 411, 412, 414, 415, 416, 417,
 418, 419, 420, 423, 424, 425, 428, 429, 430, 541
 birth rate, 336

blame, 385, 388
 blind spot, 70
 blindness, 88, 94, 111, 408
 blocks, 80, 120, 233, 395, 439
 blood, 10, 103, 297, 415, 440, 455, 461, 532, 552, 581
 blood circulation, 103
 blood flow, 297, 532, 552, 581
 blueprint, 132, 135
 body language, 299, 583
 body schema, 240, 425
 body shape, 426
 Bohr, 345
 Bolivia, 470
 bonds, 469
 bone, 10
 bootstrap, 481, 527, 534
 borderline, 377
 borderline personality disorder, 377
 boredom, 280
 borrowing, 133, 153
 Boston, 58, 110, 155, 223, 308, 426, 592
 bottleneck, 77
 bottom-up, 125, 238, 240
 boundary conditions, 130
 boys, 24, 164, 166, 167, 168, 171, 184
 BP, 291
 brachioradialis, 553, 554
 bradycardia, 455
 brain damage, 531
 brain development, 166
 brain injury, 229
 brain stem, 68, 508
 brain structure, 99, 502, 504
 brainstem, 494, 496, 503, 557, 559, 562, 563
 Brazil, 433, 470
 breakdown, 314, 329, 345, 466, 486, 533
 breakfast, 278
 breathing, 358
 brothers, 497
 Buenos Aires, 269, 270, 493, 508, 509, 510, 511, 512, 513
 buffer, 57, 94, 96, 250, 342
 building blocks, 120, 233, 373
 buildings, 161
 bulbar, 494
 burn, 10, 17
 burning, 17
 buttons, 32, 84, 285, 435
 buyer, 486

C

CAM, 326
 Canada, 223, 289, 346, 349, 401, 490, 508, 553
 candidates, 312, 315
 capacity, 273
 caregiver, 276, 277, 279, 281, 285, 286, 290
 caregivers, 273, 274, 281, 283, 285, 286, 288, 290
 Carnap, 53
 case studies, 287, 524
 case study, 186, 188, 189, 324, 325, 348, 524
 cast, 297, 581
 categorization, xiii, 61, 69, 81, 111, 142, 250, 348, 373, 409, 537, 539, 540, 543, 544, 545, 546, 547, 548, 549, 550
 category a, 30, 39, 42, 264, 518, 529, 538, 546
 category b, 19, 545
 category d, xiii, 515, 522, 523, 525, 529, 530, 532, 533, 538, 540, 541, 547, 549
 cats, xiii, 439, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 565
 causal relationship, 35, 37, 46, 475
 causality, 44, 296, 398, 406, 550, 580
 causation, 47, 547
 CBI, 274
 CD, 291
 CE, 291
 ceiling effect, 526
 celery, 516
 cell, 55, 104, 133, 212, 233, 332, 498, 504
 cell size, 212
 central nervous system, xiv, 100, 105, 552, 555, 556, 561, 563
 cerebellum, 491, 494, 499, 503, 552, 556, 562, 563
 cerebral blood flow, 532
 cerebral cortex, 18, 68, 406, 493, 500, 502, 505
 cerebral hemisphere, 166, 491, 494, 502, 508
 cerebrum, 494
 certificate, 442
 CFA, 390, 391, 475
 CFI, 390, 391, 475
 challenges, 232, 246, 291
 channels, 303, 485, 587
 chemical, 73, 86, 347
 chemicals, 298, 582
 Chi square, 206
 Chicago, 58, 60, 309, 347, 401, 593
 chicks, 429
 child development, 187, 194
 childhood, viii, 152, 154, 160, 164, 166, 170, 171, 179, 185, 188, 275, 279

-
- Chile, 470
 - chimpanzee, 53
 - chocolate, 364
 - cholinesterase, 275, 279, 290
 - cholinesterase inhibitors, 275, 290
 - chronobiology, 239
 - chunking, 252
 - cingulated, 99
 - circadian, 232
 - circadian oscillator, 232
 - circulation, 103
 - citizens, 198
 - City, 363, 372, 515
 - CK, 287
 - CL, 292
 - classes, 3, 7, 56, 125, 442
 - classical, 101, 164, 186, 228, 232, 240, 284, 315, 357, 490, 495, 497, 507
 - classical mechanics, 315
 - classification, 28, 262, 266, 413, 427, 466
 - classroom, 246, 259, 260, 261, 269, 270
 - classroom practice, 246
 - classrooms, 330
 - cleaning, 354
 - clients, 289, 290, 466
 - clinical, 273, 275, 282, 284, 285
 - clinical application, 282
 - clinical assessment, 442
 - clinical heterogeneity, 273
 - clothing, 131, 255, 351
 - clustering, 266
 - clusters, 396
 - Co, 109, 110, 227, 269, 372, 486, 507, 511
 - Cochrane, 279, 280, 281, 282, 283, 287, 289, 290, 291, 292
 - cockroaches, 439, 455
 - codes, 97
 - coding, 111, 121, 176, 248, 256, 257, 258, 262, 263, 267, 268, 544
 - coffee, 278, 286
 - cognitive, 273, 274, 275, 276, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 290, 291, 292
 - cognitive abilities, 168, 187, 192, 254, 312, 425
 - cognitive ability, 61
 - cognitive activity, 303, 304, 587, 588
 - cognitive binding, 119, 130
 - cognitive capacities, 503
 - cognitive capacity, 125, 224
 - cognitive deficit, 286, 533
 - cognitive deficits, 286, 533
 - cognitive development, 166, 170, 183, 270
 - cognitive disorders, 376
 - cognitive domains, 281, 377, 379, 386, 387, 396, 399, 400, 517
 - cognitive effort, 120, 365, 469
 - cognitive flexibility, 190
 - cognitive function, x, xv, 7, 13, 51, 57, 162, 167, 187, 191, 195, 273, 274, 286, 295, 306, 313, 530, 579, 590
 - cognitive impairment, 282, 287, 292, 522, 530, 531, 532
 - cognitive involvement, 542
 - cognitive map, 161, 186, 191, 192, 193
 - cognitive performance, xiii, 171, 195, 280, 282, 284, 515, 525, 529, 530, 544
 - cognitive perspective, 400, 461
 - cognitive process, xiii, 54, 68, 115, 119, 125, 239, 240, 249, 258, 261, 262, 263, 264, 267, 269, 303, 349, 354, 358, 362, 363, 364, 367, 371, 416, 420, 500, 504, 515, 517, 558, 563, 577, 587
 - cognitive processing, 239, 240, 303, 362, 363, 364, 371, 577, 587
 - cognitive profile, 187, 517
 - cognitive psychology, vii, ix, 1, 2, 7, 8, 9, 51, 52, 54, 112, 197, 198, 228, 250, 254, 263, 271, 350, 365, 370
 - cognitive science, 8, 109, 329, 342
 - cognitive skills, 325
 - cognitive system, 247, 251, 253, 254, 256, 257, 263
 - cognitive tasks, 251, 252, 424, 556
 - cognitive theory, xii, 57, 271, 301, 306, 308, 376, 377, 399, 400, 402, 585, 590, 592
 - cognitive therapy, 309, 402, 593
 - cognitive variables, 395
 - coherence, 72, 118, 357, 359, 360, 362, 364, 365, 370, 373
 - cohesion, 148
 - cohort, 291
 - collaboration, 3, 201, 203, 204, 206, 208, 209, 211, 212, 220, 225, 275, 442
 - Collaboration, 201, 203, 208, 210, 211, 279, 282
 - collateral, 499
 - collusion, 339
 - Colombia, 470
 - colon, 346
 - color, iv, 121, 122, 123, 124, 126, 127, 128, 129, 131, 133, 134, 153, 174, 233, 363, 463
 - colors, 82, 120, 122, 126, 128, 129, 134, 155, 421
 - combined effect, 338
 - commercial, 466, 483, 484
 - commissure, 494, 496
 - commodity, 97, 573

- common sense, 225, 345, 398
communication, 19, 25, 53, 79, 98, 239, 274, 279,
280, 281, 313, 340, 348, 349, 358, 359, 366, 442,
467, 487, 500, 503, 505, 513
communication abilities, 274
communicative intent, 366
communities, 282, 313, 328
community, 281, 287, 289, 319, 328, 379, 382, 399
Comparative Fit Index, 390
comparative research, 164
comparison task, 89
compatibility, 90, 152, 453
compensation, 102, 471, 484
competence, 81, 235, 318
competency, 314
competition, 60, 94
competitive advantage, 104
competitors, 468
complementarity, 237, 238
complexity, ix, x, xv, 18, 25, 54, 59, 68, 92, 97, 227,
232, 233, 234, 235, 250, 263, 267, 295, 297, 303,
363, 364, 371, 410, 426, 491, 520, 521, 534, 535,
579, 581, 587
compliance, 276, 466, 470, 471
components, 51, 54, 80, 95, 97, 106, 113, 122, 173,
187, 247, 253, 255, 256, 298, 304, 314, 352, 361,
380, 427, 491, 497, 502, 504, 505, 582, 588
composition, 6, 31, 35, 204, 349
compounds, 360, 361, 372
comprehension, 23, 61, 112, 255, 273, 278, 349, 371,
372, 373, 382, 516, 533
compression, 55
compulsion, 402
computer, 60, 75, 80, 101, 172, 173, 174, 175, 184,
191, 221, 287, 305, 357, 364, 366, 435, 439, 441,
462, 589
computer mouse, 441
computer simulations, 366
concentration, 166, 285
conception, xii, 55, 75, 247, 405, 414, 502
conceptualization, 402
conceptualizations, 266
concordance, 120, 534
concrete, 3, 160, 313, 315, 324, 325, 327, 328, 332,
345, 397, 415
conditioning, 170
conference, 60, 401
confidence, 122, 123, 137, 140, 146, 147, 156, 182,
201, 203, 204, 205, 206, 207, 209, 219, 220, 225,
276, 474, 577
confidence interval, 225
confidence intervals, 225
Confidence intervals, 528
configuration, 144
confirmatory factor analysis, xii, 376
conflict, 355, 357, 358, 364, 417, 464, 487, 490, 508,
512
conflict resolution, 487
confrontation, 518, 525
confusion, 313, 414, 416, 425, 436, 491, 512
congenital adrenal hyperplasia, 166
CONGRESS, iv, 377
congruence, 437
conjugation, 47
connectionist, 360, 364, 365, 414, 426, 531, 538
connectionist models, 365, 414
connectivity, 69
conscious activity, 90, 233, 234
conscious awareness, xii, 89, 95, 433, 571
conscious experiences, vii, 63, 70, 74, 76, 77, 82, 83,
100, 101, 107
conscious perception, 70, 72, 78, 80, 83, 84, 88, 91,
96, 106, 107
consensus, 125, 201, 222, 223
consent, 172, 174, 381, 442
conservation, 333
consolidation, 249, 260
constituents, 354, 358
Constitution, 198
constraints, 97, 100, 124, 125, 129, 156, 169, 186,
236, 358, 359, 360, 362, 366, 370, 418, 423, 559
construct validity, 380
construction, 18, 35, 44, 45, 46, 49, 52, 86, 90, 91,
113, 164, 235, 239, 253, 255, 260, 268, 269, 354,
355, 366, 482, 486
constructive strategies, 260
constructivism, 2
constructivist, 118
consulting, 224, 367
consumer markets, 488
consumers, xiii, 465, 466, 467, 468, 469, 470, 471,
472, 474, 482, 483, 484, 485, 488
consumption, 74, 97, 98
contamination, 400
content analysis, 223
context-dependent, 325, 356
contiguity, 126, 130
contingency, 327, 328
continuity, 59, 83, 104, 110
contour, 316, 346, 408, 410, 419
contractions, 553, 554, 555, 561, 565
contradiction, 334, 351, 568

control condition, xiv, 278, 297, 551, 555, 556, 557, 558, 581
 control group, 278, 281, 415, 438, 446, 448, 449, 450, 451, 452, 456, 518
 controlled research, 529
 controlled studies, 280
 controlled trials, 282
 controversial, 8, 474, 507
 controversies, xi, 349, 350
 convention, 209, 214, 397
 convergence, xiii, 489, 507
 conversations, 285, 330
 convex, 572
 conviction, 218, 219, 221, 377, 397, 503
 cooking, x, 228
 cooperation, xiv, 269, 359, 567
 cooperative learning, 269
 coordination, 68, 231, 251, 407, 415, 419, 420, 425, 493
 copyright, iv
Copyright, iv
 correlation, 20, 21, 22, 26, 28, 29, 30, 32, 38, 39, 76, 192, 231, 265, 326, 386, 392, 395, 475, 481, 482
 correlations, xi, 21, 25, 28, 29, 36, 38, 168, 187, 274, 303, 376, 379, 393, 394, 395, 492, 587
 cortex, 18, 68, 99, 105, 112, 150, 152, 153, 156, 406, 411, 418, 420, 431, 491, 493, 495, 496, 499, 500, 502, 503, 505, 510, 561, 563
 cortical, 289
 cortical pathway, 154
 cortical processing, 418
 cost, 80, 118, 153, 156, 384, 385, 388, 391, 435, 436, 454, 458, 460, 466, 469, 471, 474, 485
 Costa Rica, 470
 costs, xiii, 169, 465, 466, 469, 470, 471, 473, 474, 482, 483, 484, 488
 cotton, 410
 couples, 296, 580
 coupling, 302, 586
 courts, ix, 197, 198, 199, 200, 202, 221, 471
 covariate, 527
 covering, 255, 273
 CP, 245, 519, 520
 CPT, 288
 creative abilities, 503
 creativity, 371, 576
 credibility, 199, 200, 203, 205, 206, 211, 212, 213, 216, 217, 218, 219, 220, 224
 credit, 171, 203, 212, 574
 crime, 131, 199, 203, 204, 211, 213, 219
 crimes, 204

criminal justice, 220
 criminal justice system, 220
 critical analysis, 246, 362, 577
 critical variables, 195
 criticism, 246, 351, 352, 376
 cross-cultural, 398, 401, 470, 483, 486, 487, 488
 cross-sectional, 472, 522, 523, 535
 crosstalk, 231
 CT, 189, 512
 Cuba, 470
 cues, x, xv, 84, 91, 112, 115, 149, 161, 163, 166, 170, 175, 182, 183, 185, 193, 194, 276, 277, 278, 295, 306, 308, 330, 411, 418, 426, 464, 485, 488, 549, 573, 579, 590, 592
 cultural differences, 472
 cultural factors, viii, 160, 165
 cultural heritage, 504
 culture, 198, 202, 246, 247, 338, 347, 400, 472, 483, 500
 curiosity, 106
 currency, 104
 curriculum, 271
 customer relations, 487, 488
 customers, xiii, 465, 466, 467, 468, 470, 484, 485, 487
 cycles, 232, 279
 cycling, 167

D

daily living, 274, 275, 277, 278, 279, 281, 285, 288, 289, 291
 Dallas, 136, 148, 152
 damages, iv
 dance, 280
 danger, x, xv, 295, 301, 303, 304, 305, 306, 307, 380, 385, 388, 397, 399, 435, 437, 455, 579, 585, 587, 588, 589, 590, 591
 Darwinist, 114
 data analysis, 312, 318
 data collection, 204, 265, 327, 381, 542
 data distribution, 527, 531
 database, 169, 319, 335, 345
 dating, 247, 471
 death, 7, 221, 279, 315, 318, 319, 324, 327, 328, 331, 333, 336, 337, 338, 339, 340, 341, 342, 343, 435
 death rate, 315, 318, 324, 327, 328, 331, 333, 336, 337, 338, 339, 340, 341, 342, 343
 decay, 135, 148, 324
 decision makers, 573

-
- decision making, ix, xv, 119, 160, 197, 198, 200, 201, 202, 211, 212, 217, 218, 219, 222, 223, 225, 568, 569, 570, 571, 572, 575, 576, 577
 decision task, 571, 572, 573, 574, 575
 decisions, ix, xiv, 98, 197, 198, 201, 202, 203, 205, 218, 219, 220, 221, 222, 223, 235, 240, 344, 373, 378, 380, 385, 386, 387, 388, 398, 399, 459, 469, 484, 567, 568, 569, 570, 571, 573, 575, 576
 declarative knowledge, 254, 255, 256, 267
 declarative memory, 151
 decoding, 161
 deep learning, 260
 defendants, 198, 199, 221
 defense, 202, 205, 217, 218, 219, 221, 437, 455, 456, 464
 deficiencies, xiii, 312, 438, 465, 467, 468, 483
 deficit, 102, 134, 168, 283, 425, 426, 518, 521, 522, 523, 524, 532, 533, 535
 deficits, xiii, 134, 283, 285, 286, 425, 515, 517, 518, 521, 522, 523, 525, 529, 530, 531, 532, 533, 534, 535
 definition, 14, 26, 27, 28, 30, 32, 37, 45, 72, 80, 86, 90, 247, 261, 264, 322, 356, 374, 467, 516, 522
 degrees of freedom, 100, 146, 442
 delivery, 332, 462
 deltoid, 553, 554
 demand characteristic, 153
 demand curve, 337
 dementia, 155, 156, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 286, 287, 288, 289, 290, 291, 292, 516, 522, 525, 530, 531, 532, 533, 534, 535
 demographic factors, 487
 demonstrations, 278
 Denmark, 377
 density, 315, 324, 327, 342
 dependent personality disorder, 377
 dependent variable, 176, 177, 182, 395, 441, 481, 559, 574
 depressed, 284, 292, 399, 401
 depression, xi, 74, 274, 283, 285, 286, 287, 292, 376, 379, 380, 382, 394, 395, 399, 401, 402, 436, 494
 depressive symptoms, 274
 depth, 3, 6, 18, 52, 54, 172, 202, 258, 259, 267, 380, 421, 427
 derivatives, 15, 324
 destruction, 224
 detachment, 35
 detectable, 161, 320, 399
 detection, 88, 92, 93, 94, 99, 108, 111, 146, 180, 408, 410, 423, 424, 425, 429, 437
 determinism, xiv, 567
 developmental change, 543, 545
 developmental factors, 169
 developmental process, 170
 developmental psychology, 166, 168
 deviation, 449, 453
 DG, 287
 diagnostic criteria, 274, 442
 Diamond, 193
 differential psychology, 160
 differentiation, 66, 72, 80, 86, 164, 165, 171, 184, 195, 258, 392, 406, 549
 diffusion, 2, 93, 185, 269
 dignity, 285
 dimorphism, 164, 192
 directionality, 338, 417, 568
 disability, 269, 273, 274, 280, 282, 289
 disappointment, 300, 584
 disaster, 383, 389, 459, 461
 discharges, 231
 discipline, 165, 202, 261, 320, 336, 342, 344
 discomfort, 237, 365, 469
 discounts, 469
 discourse, 222
 discrete emotions, 488
 discreteness, 59, 110
 discrimination, 68, 92, 114, 408, 409, 411, 420, 425, 426, 427, 429, 430, 538, 539, 540, 541, 547, 549
 discriminatory, 410
 diseases, 90, 280, 283, 523
 disenchantment, 468
 disequilibrium, 74, 100
 dishabituation, xii, 405, 409, 410, 416, 423
 disorder, xi, 95, 186, 296, 299, 303, 304, 308, 375, 376, 379, 398, 399, 400, 401, 402, 403, 408, 438, 442, 456, 522, 580, 583, 587, 588, 592
 displacement, 187, 324, 423
 disputes, 92
 dissatisfaction, 467, 468, 469, 485, 488
 dissociation, 90, 98, 134, 143, 144, 150, 152, 502, 530, 533
 distortions, 55, 122, 175
 distraction, 300, 303, 304, 306, 307, 308, 584, 587, 588, 590, 591, 592
 distress, 379, 380, 381, 395, 398, 399
 distribution, 315, 316, 320, 322, 323, 324, 326, 327, 331, 344, 345, 485, 497, 527
 divergence, 233
 diversity, 2, 68, 269, 351, 371
 division, 497, 504
 DNA, 79, 131

dogs, xiii, 5, 15, 351, 353, 439, 455, 537, 538, 539,
540, 541, 542, 543, 544, 545, 546, 547, 548
dominance, 224, 406, 441, 443, 456, 576
Dominican Republic, 470
doors, 28
draft, 108
drawing, 118, 133, 148, 188, 189, 261, 302, 327,
345, 491, 498, 586
drinking, 286, 503
drug treatment, 288
DSM, 291, 442
DSM-IV, 442
dual task, 112, 193
dualism, 36
Duality, 512
duration, 8, 9, 76, 78, 84, 87, 103, 109, 111, 228,
234, 274, 279, 284, 319, 409, 415, 425, 427, 428,
439, 525, 538, 542, 543, 545, 548, 556, 557, 559,
560
dust, 10
dynamical system, 315
dynamism, 498
dysphoria, 436, 462

E

earnings, 466
earth, 10
eating, 53, 274
EB, 292
echoic memory, 249
ecological, 162, 202, 273, 285, 312, 348
ecologists, 312, 315, 320, 321, 338, 343
ecology, xi, 311, 312, 313, 315, 316, 319, 320, 323,
329, 330, 336, 337, 342, 344, 347
economics, 342
Ecuador, 470
Eden, 490, 508
editors, 162
education, x, 245, 246, 247, 260, 268, 271, 279, 381,
518, 525
Education, x, 192, 268, 269, 270, 348, 519, 520
educational institutions, 269
educational opportunities, 184
educational programs, 261
educational psychology, 271
educational research, 246, 261
educational settings, 271
educators, 314
EEG, 54, 59, 60, 110, 463
effortful processing, 288
egg, 10, 417
ego, 501, 502
El Salvador, 470
elaboration, 27, 76, 263, 353, 355, 440, 577
elderly, 133, 134, 166, 168, 170, 175, 184, 191, 194,
279, 280, 282, 284, 287, 288, 289, 291, 523, 525,
527, 532
elderly population, 170, 532
electrodes, 553
electroencephalogram, 60
electromagnetic, 54, 55
electromagnetic wave, 55
electromagnetic waves, 55
electron, 316, 327, 344
electron charge, 316
electronic, 277, 278, 292
electrons, 23
elephant, 365, 367, 368, 491
elephants, 538
EM, 289
EMG, 553, 554, 555, 556, 564
emission, 55
emotion, xii, 91, 109, 279, 280, 288, 301, 302, 304,
305, 308, 433, 434, 437, 461, 462, 463, 469, 485,
511, 512, 564, 585, 586, 588, 589, 592
emotional disorder, 400, 463
emotional distress, 395
emotional experience, 302, 504, 586
emotional information, xii, 308, 433, 434, 437, 443,
456, 592
emotional problems, 280
emotional reactions, 205
emotional responses, 434, 503
emotional stimuli, 199, 200, 212, 434, 435, 453
emotional valence, 200
emotions, 58, 96, 106, 222, 298, 301, 302, 305, 434,
437, 469, 488, 491, 502, 503, 585, 586, 589
empathy, 282, 467
empirical methods, 371
Empiricism, 134, 152
employees, 473
employment, 175, 186, 253, 315
encapsulated, 191
encephalitis, 516, 517, 523, 533
encoding, 132, 136, 150, 155, 160, 162, 164, 185,
199, 212, 246, 248, 250, 252, 254, 255, 256, 257,
258, 262, 264, 265, 271, 411, 421, 425, 428, 544
enculturation, 194
endocrine, 503

- energy, vii, 63, 64, 73, 74, 76, 78, 80, 85, 86, 87, 96,
97, 98, 99, 100, 101, 102, 103, 104, 106, 107,
118, 322, 328, 331, 352, 414, 504, 561
- energy constraint, 97
- energy consumption, 97
- energy input, 101
- energy supply, 97, 101
- enforcement, 133, 266, 466, 471, 472, 484
- engagement, 88, 99, 282, 435, 436, 444, 454
- engineering, 107, 240, 313, 381
- England, 113, 115, 191, 222, 347
- entropy, 101, 313
- environmental, 278, 283, 288, 289
- environmental conditions, 247, 316
- environmental factors, 164, 165, 168, 184, 188
- environmental influences, 194
- environmental variables, 169
- epidemiology, 274
- epigenetic, 427
- epinephrine, 298, 582
- epiphysis, 494
- episodic memory, 119, 156, 190, 248, 253, 270, 516
- epistemological, 272
- epistemology, 239
- equality, 43, 475
- equilibrium, 74, 76, 100, 315, 316, 320, 322, 327,
328, 337, 342, 343, 503, 565
- equilibrium price, 342
- equipment, 351
- erectile dysfunction, 299, 583
- ergonomics, 239
- essential oils, 282
- esthetics, 373
- estimating, 78, 110, 142, 144, 152, 162, 365
- estimators, 475
- estradiol, 195
- ethics, 498
- ethology, 189
- etiology, xi, 375
- EU, 471
- Europe, 254
- European Union, 456
- event-related potential, 463
- event-related potentials, 463
- everyday life, xi, 274, 277, 302, 311, 327, 345, 347,
586
- evoked potential, 233
- evolution, 13, 15, 47, 97, 102, 171, 274, 305, 322,
406, 411, 426, 490, 493, 503, 504, 506, 507, 508,
509, 524, 529, 533, 589
- exaggeration, xiii, 515, 529
- examinations, 251
- exchange relationship, 467
- excitability, 505, 563
- excitation, 308, 592
- exclusion, 143, 147, 316, 381, 392
- execution, xiv, 230, 248, 251, 252, 263, 303, 304,
305, 551, 552, 555, 558, 559, 560, 561, 562, 564,
587, 588, 589
- executive processes, 562
- exercise, 80, 265, 283, 284, 286, 292, 297, 308, 385,
389, 459, 497, 581, 592
- experimental condition, 174, 176, 179, 184, 186,
299, 301, 330, 337, 554, 583, 585
- experimental design, 170, 552, 553, 560
- expertise, xi, 311, 312, 313, 329, 338, 342, 344, 345,
347
- explicit knowledge, 240
- explicit memory, 249, 277
- exploitation, 147
- exposure, ix, 125, 151, 167, 189, 197, 198, 199, 203,
205, 206, 208, 209, 212, 214, 216, 217, 219, 220,
221, 297, 456, 547, 581
- Exposure, 210, 215, 216, 219, 462
- external environment, 302, 305, 500, 505, 586, 589
- extinction, 102
- eye, 5, 10, 54, 60, 70, 71, 115, 172, 173, 229, 233,
282
- eye movement, 70, 229, 233
- eyeball, 55
- eyes, xii, 17, 31, 70, 74, 131, 137, 174, 229, 330,
405, 407, 412, 413, 414, 415, 418, 419, 420, 430,
435, 493

F

- face validity, 367
- facies, 495
- factor analysis, xi, xii, 376, 379, 383, 386, 390, 397,
398, 401
- factorial, 270, 379, 383, 397, 438, 442, 449, 475, 574
- failure, 91, 198, 287, 360, 376, 384, 387, 397, 398,
529, 559
- fairness, 487
- false alarms, 135, 136, 137, 138, 139, 141, 148, 149
- false memory, 131, 132, 135, 150, 155
- familial, 291, 534
- families, 169, 275, 283, 285, 286, 531, 541
- family, 15, 168, 169, 187, 269, 273, 274, 275, 277,
280, 281, 285, 288, 312, 327, 495
- family members, 274
- family relationships, 281

-
- fascia, 494
 - fast food, 255
 - fat, 10
 - fatigue, 239
 - fauna, 495
 - fax, 375, 489
 - fear, 10, 12, 35, 106, 131, 296, 298, 302, 433, 437, 438, 442, 454, 462, 463, 580, 582, 586
 - fears, 296, 438, 449, 456, 580
 - feedback, xiv, 96, 102, 103, 237, 238, 276, 329, 337, 339, 340, 342, 552, 556
 - feed-back, 228
 - feed-back, 237
 - feed-back, 238
 - feeding, 406, 503
 - feelings, 73, 74, 80, 100, 104, 106, 282, 285, 302, 380, 503, 568, 586
 - females, 165, 166, 167, 168, 169, 170, 171, 179, 180, 181, 182, 183, 184, 185, 188, 192, 194, 212, 381, 394, 396, 524, 525
 - fever, 36
 - fiber, 500
 - fidelity, 195
 - fillers, 353, 370
 - film, 297, 301, 581, 585
 - films, 297, 298, 301, 581, 582, 585
 - filters, 249
 - financial, 274, 275, 469, 474
 - financial resources, 469
 - fire, 3, 5, 10, 17, 18, 59, 500
 - firms, xiii, 465, 466, 484
 - First Amendment, 198
 - first-time, 319
 - fish, 10, 351, 357, 365, 367, 368, 491, 492, 497, 539, 540
 - FISH, 357, 358
 - fitness, 284, 286
 - fixation, 87, 126, 127, 435, 439, 538, 540, 555
 - FL, 463
 - flexibility, 104, 170, 190, 283, 284
 - flexor, 553, 554
 - flexor carpi radialis, 553, 554
 - flexor carpi ulnaris, 553, 554
 - flight, 229, 357, 437, 455, 503
 - float, 10, 124, 126
 - floating, 124, 125, 139, 147, 149
 - flow, ix, 10, 73, 74, 75, 76, 80, 87, 98, 101, 102, 103, 104, 227, 237, 240, 297, 344, 415, 532, 552, 568, 581
 - flowers, 38, 54, 525
 - FLSA, 274
 - fluctuations, 201
 - fMRI, 54, 97, 420, 552, 565
 - focusing, 8, 12, 15, 16, 19, 31, 48, 49, 100, 105, 161, 246, 258, 276, 277, 314, 334, 350, 382
 - foils, 132, 136
 - folding, 45, 160
 - food, 53, 102, 255, 280, 357, 525
 - food intake, 102
 - foodstuffs, 533
 - force, xiv, 19, 96, 105, 315, 322, 324, 328, 471, 539, 551, 553, 556, 557, 563, 565
 - Ford, 171, 190
 - forebrain, 491, 492, 496, 505, 507
 - forensic, 493
 - forgetfulness, 261
 - forgetting, 250, 251
 - formal education, 271
 - formal language, 314
 - formation, x, 9, 51, 66, 67, 68, 75, 79, 80, 81, 120, 121, 122, 126, 127, 128, 129, 130, 131, 138, 139, 147, 148, 154, 191, 250, 252, 255, 257, 268, 309, 371, 494, 502, 503, 537, 538, 548, 549, 571, 576, 577, 593
 - formula, 286, 397
 - foundations, 278, 577
 - Fox, 186, 191, 437, 462, 512
 - fragmentation, 25, 26, 249
 - fragments, 253
 - framing, 115, 569, 571, 572, 573, 574, 576, 577
 - France, 58, 64, 110, 159, 405, 428, 487, 551
 - fraud, 223
 - free energy, 101, 102, 104
 - free radical, 139, 148, 150
 - free radicals, 139, 148, 150
 - free recall, 135, 138
 - freedom, 64, 82, 100, 104, 107, 146, 442
 - freezing, 437, 455, 461
 - Freud, xiii, 489, 501, 502, 511
 - Friday, 212
 - frontal cortex, 99, 105
 - frontal lobe, 185, 503
 - frontal lobes, 185, 503
 - fruits, 14, 517, 524, 525
 - frustration, 80
 - fuel, 97, 101
 - fulfillment, 467, 468
 - functional approach, 401
 - functional changes, 274
 - functional imaging, 114
 - functional MRI, 233, 564
 - functional separation, 418

functionalism, 112
 funds, 204
 furniture, 45, 367, 517, 524, 538, 539, 540, 547
 fusiform, 152, 495
 fusion, 377, 378, 380, 387, 397, 402
 fuzzy set theory, 351, 352, 358, 362, 367, 370
 Fuzzy set theory, 351
 fuzzy sets, 351, 372, 374
 Fuzzy sets, 374

G

gait, 558, 565
 games, 164, 175, 280
 ganglia, 503, 552
 ganglion, 497
 gas, 316, 323
 gases, 327
 gauge, 553
 gender, viii, 23, 92, 114, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 176, 177, 179, 180, 181, 182, 183, 184, 185, 187, 188, 189, 191, 193, 194, 303, 396, 486, 530, 531, 532, 554, 587
 gender balance, 170
 gender differences, viii, 159, 162, 163, 164, 165, 166, 167, 168, 169, 170, 176, 185, 188, 189, 194, 486
 gender effects, 530
 gender role, 169, 188
 gene, 169
 general anesthesia, 233
 general knowledge, xi, 23, 36, 311, 366
 generalization, 185, 230, 266, 277
 generalized anxiety disorder, 379, 399
 generation, 53, 148, 151, 187, 231, 262, 271
 genotype, 525, 530
 genus, 21, 32
 geography, 191
 geology, 304, 588
 geometry, 166, 184, 190
 geriatric, 286, 288, 290, 292
 Germany, 227, 229, 247, 505, 508, 537
 gestalt, 121, 126, 133, 161
 Gestalt, 76, 120, 153, 360, 365, 372, 421, 425
 Gestalt psychology, 153, 360
 Gestalt theory, 365, 372, 425
 gestation, 166
 gestures, 80, 317, 406, 428
 GFI, 390, 391
 Ghost, 507

Gibbs, 170, 190, 381, 401
 gift, 171
 girls, 164, 166, 167, 168, 171, 184
 glass, 9, 28, 31, 32
 glutamate, 70
 goal setting, 569
 goal-directed, ix, 227, 232, 235, 237, 366
 goals, 72, 79, 81, 83, 85, 96, 98, 160, 246, 261, 267, 273, 359, 363, 488, 568, 569, 571, 574, 575, 576, 577
 God, 36, 497
 gonad, 195
 Goodness of Fit, 390
 goose, 285
 grades, 266
 grading, 275
 graduate students, 165
 grants, 312, 320, 456
 granule cells, 500
 graph, xi, 146, 147, 311, 312, 313, 314, 315, 316, 317, 318, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 332, 333, 334, 335, 336, 337, 339, 340, 341, 342, 343, 344, 345, 348, 446
 grass, 4, 10, 463
 gravitational field, 316
 gravitational force, 315
 gravity, 19, 378
 Greece, 252, 489, 490
 Greenhouse, 442
 group activities, 280
 group polarization, 202, 222
 group size, 162
 group therapy, 279
 grouping, 76, 129, 148, 151, 251, 252, 504
 growth, 319, 332, 338
 growth rate, 319, 338
 Guatemala, 470
 guessing, 124, 125, 132, 138, 139, 142, 143, 209, 216
 guessing parameter, 125
 guidance, 161
 guidelines, 280, 288
 guilt, ix, 197, 201, 202, 203, 204, 205, 206, 207, 208, 211, 212, 213, 214, 217, 218, 219, 220, 296, 580
 guilty, 31, 201, 203, 204, 206, 207, 208, 211, 212, 213, 218
 guns, 221
 gyri, 502
 gyru, 495, 502

H

- H₁, 482
 H₂, 482
 habitat, 363
 habituation, xii, 405, 409, 410, 411, 415, 416, 421, 422, 423, 425, 430, 560
 hair, 10, 49, 131, 137
 Haiti, 470
 handedness, 169, 187, 189, 194, 406, 415, 426, 430
 handling, 412
 hands, xii, 46, 53, 335, 405, 406, 407, 408, 409, 410, 411, 412, 413, 418, 419, 420, 421, 423, 424, 425, 493
 hanging, 523
 happiness, 74, 106, 109
 haptic, xii, 249, 405, 406, 407, 408, 410, 411, 413, 415, 417, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 431
 hardness, 409
 harm, xi, xii, 349, 360, 362, 364, 365, 370, 375, 376, 377, 383, 384, 385, 386, 387, 388, 389, 391, 392, 393, 394, 395, 396, 397, 398, 399, 403, 458, 459, 460, 512
 harmony, xi, 349, 360, 362, 364, 365, 370, 512
 Harvard, 60, 61, 111, 114, 194, 224, 242, 347, 348, 372, 373
 hate, 363
 hazards, 303, 587
 head injury, 516
 health, 34, 280, 282, 283, 291
 health care, 282
 hearing, 9, 282, 330, 414, 423, 428
 heart, 10, 148, 150, 302, 497, 542, 559, 560, 565, 570, 575, 586
 Heart, 243, 548, 560
 heart rate, 302, 542, 559, 560, 565, 586
 heartbeat, 302, 586
 heat, 3, 17, 102, 296, 580
 heat loss, 102
 hedonic, 102, 104
 height, 31, 131, 172, 173, 339
 hemisphere, 166, 169, 192, 420, 434, 443, 453, 491, 508
 herbs, 525
 herpes, 516, 517, 523, 533
 herpes simplex, 516, 517, 523, 533
 heterogeneity, 162, 273, 328, 399, 400
 heterogeneous, 169, 423, 522, 538
 heuristic, 202, 326, 330
 high strength, 361
 higher education, 246
 high-level, 91, 255
 highways, 272
 hippocampal, 151, 494, 495, 526, 531
 hippocampus, 152, 185, 517
 histopathology, 493
 history, 37, 55, 61, 75, 247, 280, 296, 299, 306, 309, 347, 431, 580, 583, 590, 593
 holistic, 122, 126, 255, 434, 573, 577
 Holland, 242, 374
 home activities, 285
 homeostasis, 79, 232
 homes, 280, 291
 homogeneity, 442
 Honda, 227
 Honduras, 470
 honesty, 205
 horizon, 17, 233
 hormone, 168
 hormones, 166, 167, 184, 187, 189, 191, 195
 horse, 502
 horses, 502, 538
 hospital, 275, 285
 hospitalization, 274
 House, 508
 household, 367
 housing, 176
 hue, 121, 125, 129
 human animal, 167, 185
 human behavior, ix, 72, 80, 227, 228, 231, 232, 507
 human body, 565
 human brain, 58, 59, 110, 113, 415, 417, 420, 427, 429, 502, 503, 505, 507
 human cerebral cortex, 500
 human cognition, 97, 359, 365, 370
 human information processing, 115
 human psychology, xiv, 567
 humanity, 247, 568, 569
 humans, 25, 53, 161, 169, 170, 183, 185, 186, 188, 189, 190, 192, 200, 239, 350, 411, 437, 455, 491, 498, 503, 505, 517, 539, 563, 569
 humiliation, 296, 304, 580, 588
 hunting, 165, 525
 husband, 10
 hybrid, 156, 354, 358
 hybridization, 354, 358
 hyperplasia, 166
 hypertension, 171, 187
 Hypertension, 190
 hypertensive, 187, 190
 hyperthermia, 102

hypothalamic, 492, 494, 504
 hypothalamus, 494, 496, 503, 509, 562
 hypothermia, 102
 hypothesis, x, xiii, 8, 11, 34, 36, 49, 54, 68, 70, 76,
 77, 78, 83, 91, 151, 154, 167, 171, 180, 184, 185,
 200, 202, 245, 262, 267, 298, 299, 312, 319, 406,
 414, 415, 416, 418, 419, 420, 425, 434, 435, 436,
 444, 453, 454, 482, 483, 507, 522, 537, 555, 556,
 558, 569, 582, 583

I

ice, 10, 49
 ICE, 272
 iconic memory, 93, 94, 108, 249
 id, 379, 411, 501, 502, 543
 ideal, 316, 323, 327, 501, 569
 identification, 27, 88, 94, 98, 151, 156, 320, 327,
 358, 408, 409, 427, 502, 524, 532
 identity, 169, 348, 469, 572
 idiosyncratic, xi, 311
 illusion, 94
 illusions, 110, 119, 120, 123, 131, 138, 150, 153, 155
 image, 9, 172, 252, 296, 300, 319, 342, 377, 383,
 384, 389, 439, 441, 443, 444, 445, 446, 447, 448,
 450, 451, 452, 453, 454, 458, 473, 497, 520, 534,
 535, 580, 584
 imageability, 520
 imagery, 153, 191, 430, 533, 552, 553, 554, 555,
 556, 557, 559, 560, 562, 563, 564, 565
 imagination, 503
 imaging, 42, 60, 114, 233, 252, 563
 imitation, 164, 407, 415, 428, 503
 impairments, 517, 518, 522, 535
 implementation, 55, 56, 189, 231, 239, 248, 251,
 260, 262, 264, 266, 271, 358
 implicit memory, 275, 276, 277
 improvements, 279, 382
 impulses, 229, 377, 378, 384, 389, 394, 458
 impulsiveness, 277
 impulsivity, 307, 591
 in situ, 17, 88, 102, 133, 329, 339, 411, 494
 inactive, 263
 inadmissible, 201, 202, 224
 inattention, 88
 incidence, 517, 523, 534
 inclusion, 141, 143, 146, 147, 442
 incompatibility, 296, 297, 303, 453, 580, 581, 587
 incompressible, 316, 323, 327
 independence, 278, 279, 280, 282, 392, 576

independent living, 290
 independent variable, 120, 394, 574
 indexing, 343
 indication, 170
 indicators, 379, 474, 475, 481, 482, 486
 indices, 390, 391, 395, 401, 449
 indirect effect, 211, 217, 218, 225
 individual differences, 160, 161, 168, 170, 185, 186,
 188, 195, 425, 436, 442, 454, 576, 577
 individual personality, 285
 individuality, 499
 individuation, 99, 100
 induction, 149, 299, 583
 industries, 485
 ineffectiveness, 70, 199
 infancy, 405, 406, 407, 408, 411, 412, 414, 419, 420,
 424, 425, 427, 428, 429, 430, 431, 462, 548, 549
 Infants, 409, 410, 411, 412, 417, 421, 422, 423, 425,
 430, 539, 541, 547, 549, 550
 inferences, 55, 152, 254, 257, 266, 316, 317, 342,
 343, 360, 538
 inferential processing, 118
 infinite, 27, 47, 101, 506
 inflation, 482
 information processing, ix, 90, 114, 115, 160, 170,
 224, 227, 238, 240, 248, 254, 258, 259, 267, 411,
 412, 420, 426, 435, 436, 444, 456, 462
 information retrieval, 246, 248, 271
 Information System, 485
 informed consent, 442
 inheritance, 499
 inherited, 104, 358, 499
 inhibition, xiv, 91, 296, 297, 298, 300, 301, 303,
 306, 308, 309, 435, 551, 552, 554, 555, 559, 561,
 562, 563, 580, 581, 582, 584, 585, 587, 590, 592,
 593
 inhibitor, 299, 583
 inhibitors, 275, 278, 279, 290, 483
 inhibitory, x, xv, 295, 296, 298, 299, 300, 301, 303,
 306, 308, 462, 561, 563, 579, 580, 582, 583, 584,
 585, 587, 590, 592
 inhibitory effect, x, xv, 295, 296, 298, 299, 300, 301,
 579, 580, 582, 583, 584, 585
 initiation, 237, 240, 296, 511, 553, 577, 580
 injection, 298, 582
 injections, 440
 injure, 429
 injury, iv, 229, 471, 516
 innocence, 131
 insects, 491, 497, 525
 insertion, 395

insight, 234, 239, 568
 inspection, 176
 instability, 229, 481
 instinct, 79
 institutionalization, 279, 280
 instruction, 72, 79, 107, 143, 144, 146, 147, 269,
 270, 304, 320, 333, 334, 588
 instructors, 334, 342
 instruments, 164, 186, 288, 380, 525
 insurance, xiii, 465, 466, 470, 471, 472, 473, 483,
 484, 485
 integration, ix, 113, 120, 151, 152, 153, 154, 155,
 156, 161, 183, 188, 193, 227, 233, 234, 235, 238,
 240, 251, 252, 257, 354, 410, 411, 416, 419, 420,
 425, 426, 427, 430, 434, 504, 557, 565
 integrity, 355
 intellect, 491, 497, 503
 intellectual development, 282, 406
 intelligence, xiii, 53, 56, 228, 231, 254, 329, 350,
 358, 363, 365, 370, 406, 489, 502, 504, 512
 intentionality, 549
 intentions, 72, 73, 82, 83, 259, 261, 268, 472, 487,
 568
 interaction effect, 182, 445, 446, 448, 485
 interaction effects, 182, 446, 448, 485
 interactions, 65, 68, 69, 106, 282, 319, 325, 326,
 327, 355, 407, 409, 411, 442, 443, 446, 449, 462,
 468, 482, 549
 interdependence, 486, 487
 interdisciplinary, 347, 507
 interference, x, xv, 77, 175, 251, 253, 295, 300, 301,
 303, 304, 306, 307, 434, 435, 444, 453, 454, 579,
 584, 585, 587, 588, 590, 591
 interference theory, 251
 internal consistency, xi, 375, 379, 380, 382, 392,
 397, 399
 internal environment, 305, 505, 589
 international, 291
 internet, 278, 472
 Internet, 439
 interneuron, 500
 interpersonal communication, 503
 interpersonal factors, 222
 interpretability, 386
 interpretive problem, 324
 interrelationships, 265
 interval, 76, 93, 175, 234, 235, 276, 379, 392, 436,
 439, 447, 456, 557
 Intervals, 276

intervention, 89, 91, 100, 186, 275, 276, 278, 281,
 284, 287, 288, 289, 290, 291, 298, 300, 500, 505,
 541, 544, 582, 584
 interview, xi, 302, 311, 317, 318, 325, 327, 438, 442,
 586
 interviews, 314, 315, 317, 348
 intimacy, 296, 580
 intonation, 331, 332, 338
 intrinsic, 44, 46, 362, 363, 503, 527
 intrusions, 377
 intuition, 49, 572
 invariants, 411, 416, 419, 424
 inversion, 22, 30
 invertebrates, 499
 ionization, 316, 322
 ionization energy, 322
 ions, 55
 IP, 383, 384, 385, 388, 389, 390
 IR, 290, 441
 irrationality, 567, 572
 irritability, 276
 IRs, 435, 443, 444, 445, 447, 448, 449, 452, 454
 IS, 274, 291
 isolation, 32, 280, 282, 408, 423, 424
 Israel, 161
 issues, 78, 84, 162, 246, 308, 317, 350, 362, 365,
 373, 407, 429, 453, 468, 592
 Italian Operational School, 2
 Italian population, 380, 383, 386
 Italy, 1, 2, 34, 59, 63, 159, 171, 273, 375, 381, 382,
 403

J

JAMA, 292
 Japan, 241, 242, 243, 550
 Japanese, 44, 45, 110, 241, 242, 243
 Java, 141, 152
 Jefferson, 331, 347
 jobs, 321
 Jordan, 319, 327, 347, 348
 joystick, 172, 174, 175
 JT, 292
 judge, 87, 185
 judgment, ix, 142, 154, 169, 227, 228, 403, 570
 jumping, 331, 491
 Jun, 286, 291
 juries, 199, 200, 201, 202, 204, 206, 218, 220, 222,
 223

juror, ix, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 211, 212, 213, 217, 218, 219, 220, 223, 224, 225

jurors, ix, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224

jury, ix, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 208, 211, 212, 218, 219, 220, 221, 222, 223, 224

jury trial, 212

justice, 351

K

Kant, 2, 7

kill, 10, 192

kinesthetic, 407, 553

King, 547, 549

KL, 186

knee, 10

knowledge acquisition, 269

Kobe, 199, 221

L

LA, 187, 194, 270, 287, 290

labeling, 118

labor, 78

lack of control, 521

lambda, 475

language development, 59

language processing, 277

language skills, 284

languages, vii, 1, 3, 4, 6, 10, 11, 12, 13, 15, 19, 20, 21, 23, 26, 27, 29, 30, 32, 33, 34, 35, 36, 37, 38, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 53, 57, 59

large-scale, 429

latency, 435

lateral motion, 408

laterality, 438, 456

Latin-American countries, 470

law, 36, 46, 133, 219, 225, 466, 470, 471, 472, 483, 484

law enforcement, 133, 466, 472, 484

laws, 70, 343, 406, 470, 472

lead, 92, 93, 94, 95, 124, 140, 166, 199, 202, 256, 259, 260, 267, 304, 312, 314, 320, 326, 343, 351, 376, 392, 411, 416, 421, 468, 470, 481, 507, 538, 544, 548, 570, 571, 572, 573, 588

learning environment, 173, 174, 175, 178, 264, 312

learning process, x, 245, 246, 247, 248, 251, 253, 254, 256, 258, 260, 261, 262, 263, 264, 267, 268, 277, 278

learning skills, 270

learning styles, 271

learning task, 247, 258, 259, 267

left hemisphere, 166, 434, 453

left visual field, 434, 439, 443, 453

left-hemisphere, 168

leg, 10

legend, 324

legislation, xiii, 465, 466, 470, 471, 472, 482, 483, 484

legs, 83, 356, 516

Leibniz, 7

leisure, 280

lens, 75, 110, 568, 575

Lesion, 531

lesions, 186, 517

LH, 287

liability insurance, 466, 471, 472

liberation, 202

life experiences, xi, 253, 311

life span, 167, 171, 192

light, xii, xiv, 3, 10, 17, 37, 55, 84, 174, 177, 178, 179, 181, 408, 411, 417, 418, 433, 495, 502, 505, 523, 553, 554, 555, 567, 568, 575

likelihood, 138, 213, 357, 378, 383, 386, 487, 572, 577

Likert scale, 204, 205, 472

limbic system, 491, 495, 496, 503, 509, 562

limitation, 36, 74, 162, 250, 281

limitations, 127, 250, 280, 356, 364, 370, 371, 399, 456, 484

Lincoln, 152, 372

line graph, xi, 311

linear, 19, 22, 23, 24, 187, 213, 300, 305, 324, 333, 356, 395, 396, 399, 584, 589

linear regression, 395, 396, 399

lingual, 495

linguistic, vii, 1, 5, 6, 7, 8, 11, 13, 15, 16, 19, 20, 21, 24, 28, 29, 30, 37, 53, 54, 56, 57, 58, 61, 66, 81, 95, 129, 151, 155, 314, 318, 345, 361, 366, 370, 371

linguistic information, 61

linguistic representation, 129

linguistics, vii, 1, 2, 5, 6, 7, 13, 25, 27, 28, 30, 31, 36, 45, 52, 60, 61, 350, 360, 370

links, xii, 12, 21, 298, 299, 405, 418, 420, 469, 582, 583

liquid phase, 316

liquids, 327
 liquor, 436
 listening, 83, 89, 93, 110, 115, 282
 literature, 279, 280, 283, 284, 288, 291
 liver, 10, 165, 497
 localised, 563
 localization, 18
 location, 88, 92, 93, 94, 95, 126, 127, 128, 130, 133,
 134, 135, 161, 162, 164, 169, 176, 183, 185, 191,
 193, 195, 255, 279, 303, 324, 340, 412, 415, 435,
 439, 441, 445, 495, 531, 587
 location information, 130, 134
 loci, 252
 locomotion, 185, 406
 locomotor, 161
 locus, 99, 531
 locus coeruleus, 99
 London, 59, 60, 61, 108, 110, 202, 223, 224, 307,
 309, 329, 372, 429, 430, 463, 486, 507, 508, 510,
 511, 512, 535, 591, 593
 long distance, 182
 long period, 17
 longevity, 135
 longitudinal study, 531, 534, 539, 549
 long-term memory, 26, 64, 71, 247, 248, 249, 255,
 259, 503, 544, 573
 loss of consciousness, 97
 losses, 571, 572, 573, 574
 love, 36, 43, 106, 279, 363
 lover, 296, 580
 low-level, 90, 91, 289
 loyalty, 467, 469, 474, 487, 488
 lying, 415

M

M.O., 426
 Macedonia, 489
 Mach, E., 112, 241
 machine translation, vii, 1, 2, 55, 56, 58, 59, 60
 machinery, 231, 232, 234, 238, 239
 machines, 112, 367, 368
 magazines, 21, 22, 24
 magnet, 315
 magnetic, 315, 316
 magnets, 315
 magnitude, 42, 77, 165, 167, 324, 555
 maintenance, xi, 258, 285, 290, 375, 456
 Maintenance, 285
 major issues, 353, 362, 370

majority, 4, 5, 6, 27, 40, 148, 199, 201, 202, 205,
 219, 220, 305, 370, 470, 472, 517, 523, 526, 589
 males, 164, 166, 167, 168, 170, 171, 179, 180, 181,
 183, 184, 192, 212, 382, 394, 396, 524, 529
 mammal, 491, 492, 495, 547
 mammalian brain, 509
 mammals, 170, 406, 411, 503, 505, 538, 539
 man, 5, 10, 16, 17, 23, 30, 31, 32, 49, 53, 111, 131,
 204, 240, 282, 373, 429, 491, 497, 510, 524, 534,
 563, 565
 management, 264, 280, 283, 285, 292, 305, 466, 486,
 589
 manipulation, 162, 165, 194, 301, 302, 314, 406,
 411, 429, 456, 572, 585, 586
 man-made, 524, 534
 manners, 41
 mapping, 60, 192, 193, 355, 562
 market, 485
 market segment, 485
 marketing, 465, 467, 474, 485, 486, 487, 488
 markets, 466, 488
 marriage, 279
 marrow, 496
 Marxism, 348
 mask, 160, 522
 masking, 89, 110, 112, 170, 533
 Maslach Burnout Inventory, 401
 mass, 305, 589
 Massachusetts, 111, 113, 240
 material resources, 314, 323, 325, 345
 materials, 78, 125, 127, 128, 131, 133, 134, 149,
 259, 263, 285, 315, 318, 324, 574
 mathematicians, 350
 mathematics, 42, 188, 314, 347
 matrix, 365, 386, 392, 475, 503
 matter, iv, 10, 11, 35, 43, 59, 91, 101, 176, 334, 384,
 387, 461, 487, 495, 502, 577
 MCI, 278, 290, 292
 MCP, 250, 251, 252, 253, 263, 266
 meanings, vii, 1, 2, 3, 6, 7, 8, 11, 13, 15, 17, 20, 22,
 23, 25, 28, 30, 35, 36, 40, 43, 44, 47, 49, 51, 54,
 57, 66, 71, 82, 83, 149, 263, 268, 313, 361, 367,
 370, 372, 516
 measurement, 43, 154, 189, 401, 471, 472, 474, 475,
 481, 482, 487, 488, 576
 measurements, 297, 298, 299, 303, 474, 475, 554,
 581, 582, 583, 587
 meat, 10
 media, 198, 202, 224, 225, 248, 267, 401
 median, 315, 441, 496
 mediation, 211, 217, 218, 219, 507

-
- mediators, 217, 218, 307, 324, 591
 medical, 274, 281, 283, 308, 466, 592
 medical care, 281, 283
 medicine, 254, 493, 505, 512, 572
 medulla, 494
 medulla oblongata, 494
 MEG, 54
 membership, 77, 138, 351, 357, 364, 470, 546
 memorizing, 105, 252, 261, 420
 memory capacity, 26, 58, 61
 memory deficits, 517
 memory function, 247, 305, 589
 memory loss, 531
 memory performance, 133, 138, 144, 150, 183, 199, 223, 529
 memory processes, 139, 142, 143, 144, 145, 146, 147, 164, 256, 409
 memory retrieval, 573
 men, xiii, 31, 162, 163, 164, 166, 167, 171, 184, 187, 188, 189, 191, 193, 194, 195, 203, 296, 297, 299, 303, 307, 308, 309, 438, 515, 524, 525, 529, 532, 580, 581, 583, 587, 591, 592, 593
 mental activity, 91, 93, 96, 98, 113, 360
 mental image, 9, 69, 92, 153, 342, 378, 380
 mental imagery, 153
 mental life, 10, 100, 378
 mental model, 190, 255
 mental operations, vii, 1, 2, 7, 8, 10, 18, 36, 54, 57, 234, 552
 mental processes, 75, 561, 563
 mental representation, 16, 43, 118, 163, 170, 175, 182, 183, 194, 352, 409, 552, 556, 557, 559
 mental state, 279, 298, 505, 582
 mental states, 505
 mentor, 491, 505
 mergers, 250
 Merleau-Ponty, 95
 mesencephalon, 497
 messages, 577
 meta analysis, 570
 meta-analysis, 155, 162, 187, 193, 195, 518, 522, 525, 575, 576
 metabolic, 97
 metacognition, 261, 263, 264
 metacognitive knowledge, 264, 267, 268
 metaphor, 54, 68, 97, 502
 metaphors, 75, 97
 metazoans, 497
 meteorological, 44
 methodological procedures, 381
 methodology, xii, 58, 108, 148, 225, 264, 405, 411
 metric, 162, 163, 164, 347, 475
 Mexico, 269, 270, 271, 470
 mice, 167, 189
 microeconomics, 343
 microelectrode, 565
 microstructure, 428
 microtubules, 67, 70
 midbrain, 68, 491, 494, 503
 Middle Ages, 28
 middle-aged, 274, 275, 280, 284, 286
 migration, 154
mild cognitive impairment, 287, 292, 530, 531
 mild cognitive impairment (MCI), 292
 military, 261
 mimicry, 571, 576
 miniature, 541
 Ministry of Education, 529
 mirror, 221, 397
 misinterpretation, xi, 375
 misleading, 89, 160
 missions, 401
 MIT, 58, 61, 110, 112, 113, 114, 152, 154, 190, 191, 223, 240, 241, 242, 372, 425, 426, 427, 428, 430, 512, 531
 mixing, 414
 ML, 290
 MMSE, 278, 279, 284, 519, 520
 mobility, 283
 modalities, xii, 66, 76, 77, 83, 88, 92, 105, 106, 232, 249, 405, 408, 411, 412, 414, 415, 416, 417, 418, 419, 420, 423, 424, 425, 426, 429, 533, 552, 554
 modality, xii, 17, 41, 42, 43, 76, 77, 105, 106, 112, 221, 233, 405, 406, 407, 411, 412, 414, 415, 416, 417, 418, 420, 422, 426
 modeling, 146, 231, 313, 316, 329, 485, 486
 moderators, 223, 469, 488
 modifications, 14, 23, 30, 55, 106, 185, 301, 382, 561, 565, 585
 modulation, 76, 95, 99, 104, 109, 114, 332, 443, 454, 456, 462
 modules, 83, 96, 105, 107, 233
 modus operandi, 301, 585
 momentum, 328
 money, 46, 49, 221, 280, 468, 470, 473, 474
 monkeys, 42, 411, 426, 427, 428
 Monroe, 486
 Monte Carlo, 485
 Monticello, 375
 mood, xi, 3, 29, 48, 51, 52, 276, 280, 283, 285, 286, 291, 292, 307, 308, 376, 436, 455, 591, 592
 mood disorder, 376

morality, 398
 morning, 24
 morphemes, vii, 1, 4, 5, 7, 11, 13, 16, 28, 56
 morphological, 26, 29, 48
 morphology, vii, 1, 4, 23, 26, 51, 55, 57
 motion, 233, 408, 418, 421, 422, 427, 431, 548, 549, 550, 568
 motivation, 57, 98, 104, 261, 264, 307, 372, 437, 462, 503, 559, 591
 motives, 325, 335, 474, 569, 575
 motor actions, 437, 563
 motor activity, 280, 558
 motor area, 99, 491, 552, 565
 motor behavior, 394, 395, 396, 398
 motor control, ix, 227, 415, 558
 motor coordination, 231
 motor skills, 253
 motor system, 233, 420, 504, 561
 motor task, 552, 558, 559
 motorcycles, 539
 mouth, 10, 53, 406, 407, 414, 425, 426
 MRI, 233, 564
 MS, 60, 287, 292
 multidimensional, 68, 164, 273, 290
 multimedia, 278, 292
 multiple interpretations, 359
 multiple regression, 481
 multiplication, 482
 multivariate, 403
 multivariate statistics, 403
 murder, 31, 203, 204, 435
 muscle, xiv, 504, 551, 552, 554, 556, 558, 562, 564
 muscle contraction, xiv, 504, 551, 552, 554, 564
 muscles, 552, 553, 554, 555, 556, 557, 558, 559, 561, 562, 564
 musculoskeletal, 76, 78
 musculoskeletal system, 76, 78
 music, 93, 119, 253, 280, 281, 282, 289, 291, 292, 414
 music therapy, 281
 mutilation, 461

N

NA, 208, 519, 520
 NAc, 519, 520
 naming, 304, 308, 463, 464, 497, 516, 518, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 588, 592
 National Academy of Sciences, 110, 111, 113, 114, 151, 156, 429

National Institute of Mental Health, 494
 National Research Council, 2
 natural, 5, 28, 44, 48, 92, 111, 184, 228, 306, 312, 313, 318, 348, 370, 372, 437, 453, 508, 524, 534, 539, 540, 549, 590
 natural science, 312
 natural sciences, 312
 navigation system, 235
 Nebraska, 152, 372
 neck, 10, 12, 426
 negative affectivity, 436, 438
 negative consequences, 379, 385, 387, 398, 459
 negative emotions, 298, 434, 582
 negative mood, 308, 436, 592
 negative priming, 90, 115
 negative valence, 444, 455, 456, 573
 negativity, 200, 212, 213, 217, 218, 219, 224, 463
 neglect, 185, 253, 488
 neocortex, 231, 491, 500, 503, 504, 508
 neon, 155
 neonatal, 166, 407, 414
 neonate, 412, 431
 neonates, 409, 412, 417, 425, 428
 nerve, 494, 498, 504
 nervous system, xiv, 97, 100, 105, 232, 233, 308, 411, 497, 499, 504, 505, 552, 556, 559, 561, 562, 563, 564, 565, 592
 Netherlands, 348, 428
 network, 21, 22, 23, 24, 25, 27, 28, 29, 39, 45, 70, 96, 99, 114, 231, 360, 364, 365, 502, 504
 neural function, 97
 neural mechanisms, 68, 430, 524, 561
 neural network, 70, 96, 114, 190
 neural networks, 190
 neural systems, 463
 neuroanatomy, 490, 492, 493, 502
 neurobehavioral, 490, 508
 neurobiological, 54, 83, 512
 neurobiology, xiii, 2, 489, 493, 495, 504, 505, 507
 neurodegenerative, 283
 neurodegenerative disease, 283
 neurodegenerative diseases, 283
 neuroimaging, 418
 neurolinguistics, 2, 52
 neurologist, 490
 neuronal systems, 236
 neurons, 18, 42, 54, 65, 68, 70, 78, 185, 230, 233, 365, 500, 504
 neuropathological, 493
 neuropathology, 517, 530
 neurophysiology, 228

Neuropsychiatric Inventory, 274, 287
 neuropsychological assessment, 193
 neuropsychological tests, 273, 275
 neuropsychology, 108, 113, 193
 neuroscience, xiii, 54, 61, 113, 155, 425, 489, 497,
 501, 505, 508, 509, 511, 512
 neutral, x, xv, 199, 219, 223, 295, 297, 304, 306,
 322, 434, 435, 436, 438, 439, 441, 443, 444, 453,
 456, 506, 572, 579, 581, 588, 590
 neutrons, 23
 New England, 191
 New Jersey, 577
 New Orleans, 187, 194
 newspapers, 223, 284
 Nicaragua, 470
 Nietzsche, xiv, 567
 nigrostriatal, 504
 NO, 565
 noise, 46, 419
 non-biological, 97
 non-clinical, xi, 299, 300, 375, 378, 379, 381, 382,
 398, 399, 401, 402, 463, 583, 584
 non-clinical population, 382
 nonconscious, 576
 non-human, 167
 nonparametric, 526
 non-pharmacological, 281, 282
 non-pharmacological treatments, 281
 non-random, 517
 non-randomness, 517
 normal, xi, xiii, 10, 90, 102, 131, 134, 166, 171, 229,
 239, 298, 303, 330, 332, 346, 375, 379, 380, 399,
 402, 408, 425, 429, 461, 482, 515, 523, 524, 527,
 533, 534, 582, 587
 normal aging, 134, 534
 normal distribution, 527
 norms, 440, 530, 534, 535
 nose, 5, 10, 36, 137
 novel stimuli, 462
 novelty, 105, 106, 189, 410, 428, 538, 542
 NS, 381, 396
 nuclei, 492, 496, 508
 nucleus, 327, 345, 493
 nuisance, 521, 522, 523, 527, 529
 null, 194, 208, 484
 nurses, 401
 nursing, 274, 280, 283, 290, 291, 292
 nursing home, 274, 280, 283, 291, 292
 nutrient, 327

O

obedience, 246
 object recognition, 189, 427, 516, 517, 533
 objectivity, 205
 obligation, xiii, 201, 465, 466, 470, 471, 483, 484
 observations, 33, 41, 69, 122, 233, 234, 239, 296,
 297, 357, 367, 538, 580, 581
 obsessive-compulsive, xi, 375, 379, 399, 401, 402,
 403
 obsessive-compulsive disorder, xi, 375, 379, 399,
 401, 402
 obstacles, 163, 246, 469
 occipital lobe, 133
 occlusion, 421
 occupational, 275, 281, 288
 occupational therapy, 281, 288
 OCD, xi, xii, 375, 376, 377, 378, 379, 380, 381, 382,
 393, 394, 395, 396, 398, 399, 400, 401
 octopus, 356, 516
 oculomotor, 99, 231, 238
 offenders, 308, 592
 officials, 133
 Ohio, 485
 oils, 282
 old age, viii, 160, 167, 170, 171, 179, 185
 older adults, 151, 156, 530, 565
 older people, 287, 289
 olfaction, 503
 olfactory, 491, 492, 494, 495, 496, 498
 olfactory bulb, 492, 494, 496
 omission, xii, 376, 378, 387, 391, 392, 393, 394,
 395, 396, 397, 398, 399, 401
 one dimension, 353
 online, 270, 355, 363, 364, 371, 485, 487
 on-line, 124, 176
 on-line, 540
 on-line, 548
 open space, 189, 190
 open spaces, 189
 openness, 238
 operating range, 234
 operating system, 75, 253
 operational semantics, 2
 Operational Semantics (OS), vii, 1, 2
 operator, 232, 370
 opportunities, 83, 280, 284, 468
 opposition, 12, 167
 optic nerve, 494
 OR, 249, 346
 oral, 278, 407, 412, 424

organ, viii, 19, 63, 64, 68, 71, 73, 74, 75, 76, 77, 78, 80, 84, 87, 95, 98, 99, 100, 103, 104, 106, 107, 231, 254, 260, 297, 490, 581
 organic, 98, 299, 306, 496, 583, 590
 organism, vii, 63, 64, 71, 72, 73, 74, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 86, 91, 101, 102, 107, 230, 420, 437, 497, 505, 552, 561
 organizational development, 251, 252, 267
 organize, 246, 247, 248, 250, 254, 255, 261, 362, 548
 organs, 64, 71, 73, 74, 75, 76, 77, 78, 82, 84, 87, 95, 97, 98, 104, 228, 229, 231, 303, 406, 407, 505, 587
 orgasm, 299, 303, 583, 587
 orientation, xi, 108, 151, 161, 169, 170, 175, 176, 182, 184, 186, 187, 188, 189, 192, 274, 279, 282, 287, 290, 291, 292, 327, 329, 332, 333, 334, 335, 349, 358, 360, 362, 366, 369, 370, 430, 474, 500
 oscillation, 233
 oscillations, 67, 70, 104, 115, 233
 oscillatory activity, 233
 outpatients, 291, 379
 overlap, 23, 99, 124, 136, 148, 149, 247, 316, 317, 334, 379, 381, 399
 overlay, 335, 336, 341
 overload, 77
 overtraining, 186, 563
 ownership, 96

P

PA, 60, 274, 290, 349
 Pacific, 109
 packets, 204, 205
 pain, 45, 55, 64, 74, 80, 102, 104, 105, 106, 487
 pairing, xv, 366, 414, 568
 Panama, 470
 panic disorder, 296, 304, 308, 580, 588, 592
 paradoxical, 518, 533
 Paraguay, 470, 495
 parallel, 69, 77, 101, 120, 121, 128, 151, 231, 237, 339, 341, 360, 364, 408, 504, 539
 parallel processing, 151, 408
 parameter, 125, 146, 324
 parameter estimates, 146
 paraphilia, 296, 580
 parasympathetic, 296, 580
 parasympathetic activity, 296, 580
 parental care, 503
 parents, 169, 172, 221, 544, 550
 parietal cortex, 99, 150, 500
 Paris, 58, 108, 113, 115, 159, 265, 309, 347, 405, 426, 427, 428, 512, 593
 parity, 165
 PART, 246, 264
 Partial Least Squares, 481
 particles, 23, 37
 partnership, 247, 487
 partnerships, 259
 passive, 26, 32, 35, 44, 45, 47, 48, 75, 91, 194, 259, 260, 267, 280, 408, 422, 455, 500
 pathology, 131, 517
 pathways, 69, 154, 420, 492, 502, 552, 563
 pattern recognition, 258
 PD, 290
 peace, 383, 389, 457
 pearls, 417
 pedagogical, 271
 peer, 317, 346
 peer review, 346
 peers, 168, 319, 329
 penalties, 470
 penalty, 175
 pendulum, 315, 316
 penetrability, 565
 penis, 297, 581
 Pennsylvania, 349
 percentile, 394
 perceptions, ix, 25, 72, 80, 82, 83, 84, 118, 121, 123, 124, 132, 150, 197, 217, 219, 224, 239, 343, 399, 408, 414, 483, 487, 488
 perceptual component, 120
 perceptual learning, 152, 426
 perceptual processing, 77, 98, 119, 122, 123, 125
 perfectionism, 378, 379, 380, 385, 386, 397, 399, 400
 performance, 274, 284, 289, 290, 291
 Peripheral, 551
 permission, iv, 169, 490
 permit, 90, 482, 549
 personal, 276, 277, 279, 286
 personal communication, 79, 98, 442
 personal computers, 175
 personal life, 260
 personal relations, 466, 469, 486
 personal relationship, 466, 469, 486
 personal relevance, 573
 personal responsibility, 377
 personal values, 569, 573
 personality, 222, 280, 285, 299, 307, 377, 401, 576, 583, 591
 personality disorder, 377, 401

- Personality disorders, 377
 persuasion, 224
 perturbation, 102, 186, 563
 perturbations, 97, 102, 156
 Peru, 470, 516
 PET, 54, 97, 191, 357, 358, 365, 419
 petrographic, 344
 petroleum, 344, 347
 Petroleum, 347
 pets, 351
 phalanx, 560
 pharmacological, 281, 282, 308, 438, 592
 pharmacological treatment, 281, 282
 phenomenal consciousness, 55, 106
 phenomenology, 108, 118, 120, 122, 141, 153
 Philadelphia, 59, 62
 philosophers, 64
 philosophical, 2, 36, 356, 412, 414, 504, 505
 philosophy, 2, 7, 51, 348, 350, 370, 428, 505
 phobia, 296, 303, 304, 307, 308, 376, 436, 442, 454, 461, 462, 580, 587, 588, 591, 592
 phobic stimulus, 438, 446, 447
 phone, 250, 489, 541
 phonemes, 346
 phonological, 156, 258, 259, 516
 phonology, 148
 photosynthetic, 322
 phylogenesis, 508
 phylogenetic, 491, 497, 502, 505
 phylogeny, xiii, 489, 498, 500, 502, 507
 physical activity, 283, 289
 physical characteristics, 259
 physical chemistry, 314, 326, 327
 physical environment, 53, 161, 186, 467, 474
 physical exercise, 298, 582
 physical fitness, 283
 physical health, 283
 physical laws, 406
 physical properties, 420
 physical structure, 100, 524
 physical world, 7, 55, 65, 420
 physicists, x, 311, 312, 314, 315, 317, 320, 321, 322, 323, 324, 325, 328, 329, 338, 343, 344, 345, 348
 physics, xi, 311, 312, 313, 314, 315, 316, 318, 319, 320, 321, 322, 323, 324, 327, 328, 329, 338, 342, 344, 345
 physiological, 96, 102, 103, 106, 239, 296, 297, 301, 302, 303, 308, 309, 382, 434, 500, 504, 559, 561, 580, 581, 585, 586, 587, 592, 593
 Physiological, 60, 242, 243, 548, 560
 physiological mechanisms, 297, 561, 581
 physiological psychology, 504
 physiological regulation, 239
 physiologists, 228, 504
 physiology, 97, 99, 490
 piano, 331, 332, 346
 pilot study, 278, 288, 290, 292
 pineal, 494
 pitch, 318, 331, 332, 346
 placebo, 281, 298, 582
 planning, 89, 221, 261, 266, 552, 561, 564
 plant type, 525
 plants, 322, 326, 497, 531, 539
 plasticity, 289, 564
 platform, 234, 235, 318
 Plato, xiii, 489, 496, 497, 502, 510
 plausibility, 64, 74, 103, 154, 355, 358, 359, 362, 366, 369
 play, vii, 1, 7, 10, 34, 36, 72, 83, 122, 140, 164, 168, 169, 239, 248, 258, 263, 301, 355, 362, 371, 503, 523, 538, 539, 548, 563, 585
 playing, 34, 221, 231, 407
 pleasure, 43, 64, 80, 102, 103, 104, 105, 106, 284, 296, 580
 plethysmography, 297, 303, 581, 587
 PLS, 481, 482, 486
 PM, 287
 PN, 288
 polarization, 202, 222, 504
 police, 26, 48, 222, 225
 policy, 471, 474, 508
 politics, 239, 261
 poor, 8, 165, 169, 189, 277, 360, 467, 469, 471, 474, 522
 population density, 324
 population size, 315, 322, 324, 328, 331, 333, 334, 335
 Positive and Negative Affect Schedule, 441
 positive mood, 286, 436
 positivism, 505
 post-stroke, 565
 posttraumatic stress, 308, 592
 post-traumatic stress, 304
 post-traumatic stress, 588
 posttraumatic stress disorder, 308, 592
 post-traumatic stress disorder, 304
 post-traumatic stress disorder, 588
 postural control, 558, 565
 posture, 461, 494, 558, 565
 potassium, 55
 potato, 360

- power, 50, 78, 80, 87, 101, 300, 304, 356, 378, 379, 385, 389, 396, 459, 464, 564, 576, 584, 588
- pragmatic, xi, 349, 358, 359, 362, 366, 367, 370, 556
- predicate, 26, 48, 253, 366
- predictability, 118, 386
- prediction, 96, 121, 203, 222, 231, 232, 327, 559, 572
- predictive validity, 291
- predictor variables, 521
- predictors, xii, 376, 399, 481
- predisposing factors, 466, 467, 481, 482, 483
- pre-existing, xiii, 363, 515, 526
- preference, xii, 275, 357, 405, 413, 414, 415, 416, 428, 430, 538, 572, 573, 574, 575, 576
- pregnant, 168, 296, 580
- premotor cortex, 420, 563
- preparation, iv, xiv, 99, 250, 257, 262, 263, 268, 455, 551, 552, 558, 559, 561, 562, 564
- preparedness, 454
- preschool, 166
- preschoolers, 192, 284
- preservation, 80, 247, 503, 505, 506, 522, 531, 535
- press, 221
- pressure, 297, 299, 317, 417, 565, 581, 583
- pretrial, 198, 214, 220, 221, 222, 223, 224, 225
- prevention, 378, 391, 397
- prices, 468, 577
- primacy, 183
- primary data, 66
- primary school, 6, 182, 183, 192, 194
- primary senses, 282
- primary visual cortex, 153
- primate, 431, 498
- primates, 406, 411, 492, 495, 508
- priming, x, xv, 89, 90, 113, 115, 295, 297, 299, 301, 302, 303, 306, 372, 576, 579, 581, 583, 585, 586, 587, 590
- primitives, 6, 7, 10, 11, 41, 59, 61, 62, 548
- principles, 60, 72, 76, 78, 79, 81, 122, 126, 129, 130, 147, 148, 150, 266, 283, 358, 359, 366, 548
- prior knowledge, 246, 247, 251, 257, 263, 266, 267
- privacy, 283
- private, 471, 472, 490
- probability, xiii, 91, 124, 140, 143, 145, 146, 148, 327, 442, 455, 515, 525, 529, 577
- probe, 112, 123, 297, 462, 463, 516, 581
- problem behavior, 281, 290
- problem behaviors, 290
- problem solving, 169, 253, 261, 271, 283, 312, 357
- problem-solving, 347
- procedural knowledge, 254, 255, 256, 344
- procedural memory, 24, 25, 248, 275, 278, 281, 285, 293
- procedural rule, 356, 357
- procedures, 276, 277, 283, 288
- processing biases, 462, 529
- processing stages, 77
- procreation, 437
- production, 24, 25, 54, 73, 81, 83, 87, 97, 98, 99, 100, 101, 102, 273, 301, 314, 331, 332, 339, 340, 342, 371, 533, 585
- productivity, 507
- professionalism, 473
- prognosis, 288
- program, xiv, 11, 55, 56, 176, 221, 234, 237, 273, 275, 278, 279, 281, 283, 285, 286, 287, 291, 292, 314, 315, 316, 318, 330, 347, 488, 552, 559, 563, 574
- programming, 441, 552, 561
- progressive, 273
- project, 2, 55, 271, 289, 320, 342, 456
- propagation, 364
- property, 352, 353, 354, 355, 356, 362, 366, 368, 369, 370, 372, 407, 408, 415, 416, 417, 418, 428, 482
- proposition, 15, 492, 504, 505, 568, 570
- propulsion, 565
- prosecutor, 217, 218
- prospect theory, 569, 571, 572
- prospective memory, 276, 278
- prosthesis, 283
- protection, 209
- protocol, 281, 286, 329, 335, 339
- protocols, 314, 318, 325
- prototype, 5, 352, 357, 358, 362, 364, 365, 366, 367, 369, 370, 372, 373, 374
- prototypes, 139, 357, 373
- PRP, 77, 98
- PSA, 373
- pseudo, 168, 174, 302, 586
- PSI, 456
- psyche, 51, 108, 109, 113, 114, 496, 497, 502
- psychiatrist, 490
- psychiatry, 51, 231, 288, 401, 509
- psychic energy, 97, 98
- psychoanalysis, xiii, 489
- Psychoanalysis, 501
- psychobehavioural, 273, 274
- psychobiology, 507
- psycholinguistics, vii, 1, 2, 25, 52, 53, 54, 332
- psychological distress, 395
- psychological phenomena, 87, 497

psychological processes, 97, 255, 266, 348
 psychological variables, 289
 psychologist, 247, 281, 318, 319, 340, 381
 psychometric approach, 160
 psychometric properties, xii, 376, 379, 396, 402, 442, 474
 psychopathology, 287, 400, 402, 496
 psychophysiology, 463
 psychosocial, 284, 286, 289, 292
 psychosocial factors, 165
 psychosomatic, 512
 Psychosomatic, 511
 psychotherapeutic, 400
 psychotherapy, 280, 281
 PT, 288
 PTSD, 308, 592
 puberty, 166, 168
 public, 2, 198, 199, 221, 312, 321, 323, 332, 466
 public opinion, 221
 public sector, 312, 321, 323
 public service, 466
 publishing, 269
 pulse, 72, 107
 pupils, 182, 183, 266, 268, 269
 Purkinje, 500
 Purkinje cells, 500
 P-value, 554
 pyramidal, 493, 562

Q

quadriceps, 565
 Qualia, 64, 114
 qualifications, x, 245
 qualitative differences, 258
 qualitative research, 315
 quality of life, 273, 281, 288
 Quality of life, 279
 quality research, 281
 quantitative research, 264
 quantum, 70, 316
 quantum mechanics, 316
 query, 335, 338, 339, 340
 questioning, 345, 516
 questionnaire, xi, 141, 175, 185, 203, 205, 213, 375, 378, 381, 382, 400, 402
 questionnaires, 379

R

R&D, 227
 RA, 287, 553
 race, x, 134, 148, 245
 radiation, 55, 496
 radicals, 139, 148, 150
 radius, 172, 173, 174, 345
 rain, 10, 44
 random, x, 3, 4, 174, 245, 302, 305, 439, 441, 517, 586, 589
 random access, 305, 589
 range, 6, 43, 64, 160, 205, 212, 221, 234, 239, 246, 265, 268, 274, 322, 354, 371, 381, 392, 394, 441, 516, 541, 544, 548
 rape, 296, 304, 580, 588
 rash, 304, 588
 rat, 425, 430
 rating scale, 401
 ratings, 203, 204, 205, 206, 207, 208, 209, 211, 212, 213, 216, 217, 218, 219, 220, 365, 441, 452, 457, 463
 rationality, 503, 569, 572, 575, 576
 rats, 166, 167, 189, 194, 195, 327, 411, 455
 raw material, 72, 79, 81
 RC, 286
 reaction time, 90, 233, 239, 304, 435, 437, 438, 453, 454, 500, 588
 reactions, 66, 104, 105, 106, 107, 205, 222, 309, 407, 437, 455, 456, 461, 487, 493, 499, 593
 reactivity, 297, 301, 581, 585
 reading, 28, 111, 155, 175, 205, 246, 304, 320, 326, 327, 330, 332, 333, 334, 336, 339, 342, 344, 345, 373, 382, 588
 reading comprehension, 373
 real time, 330, 500
 reality, 50, 51, 52, 154, 175, 186, 187, 193, 223, 239, 247, 248, 254, 256, 279, 282, 302, 303, 305, 325, 497, 503, 507, 530, 568, 586, 587, 589
 reasoning, 200, 223, 231, 318, 322, 341, 348, 420, 425, 429, 504, 507
 recall, 10, 24, 131, 132, 133, 135, 138, 139, 145, 151, 154, 155, 162, 199, 200, 205, 212, 222, 223, 225, 247, 251, 253, 258, 261, 276, 279, 282, 287, 507
 recall information, 258
 recalling, 133, 161, 219
 reception, 408, 505
 receptors, 230, 406, 416, 420
 recession, 31
 reciprocal cross, 419

-
- reciprocal relationships, 27
 - recognition test, 140, 141, 143, 144, 198, 415
 - recollection, 120, 135, 136, 137, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 156, 157, 161
 - recombination, 25
 - recommendations, iv, 194, 225, 281
 - reconcile, 65, 356
 - reconciliation, 504
 - reconstruction, 23, 255, 264, 408
 - recovery, x, 245, 248, 250, 252, 254, 256, 257, 262, 263, 264, 267, 268, 421, 487, 535, 563
 - recovery process, 252, 256, 263
 - recreation, 280, 288
 - recreational, 275, 280, 281, 284, 286, 288
 - rectilinear, 410
 - reduction, 277, 281, 282
 - refining, 121, 123
 - reflection, 46, 246, 263, 267, 268, 360, 380
 - reflexes, 407, 409, 497
 - reform, 270
 - refractory, 98
 - regional, 97, 532
 - Registry, 284
 - regression, xii, 66, 67, 74, 107, 211, 218, 376, 380, 395, 396, 399, 482, 529
 - regression analysis, xii, 376, 395, 396
 - regression equation, 211, 218
 - regression model, 399
 - regular, xiii, 228, 232, 234, 276, 537, 541, 544
 - regulation, 72, 101, 102, 472, 494, 503, 558, 561, 563
 - regulations, xiv, 239, 552, 558, 562
 - rehabilitate, 280
 - rehabilitation, xiv, 186, 273, 274, 275, 276, 278, 284, 285, 286, 287, 288, 292, 552, 563, 564, 565
 - rehabilitation program, 273, 275, 278, 286, 287, 292
 - reinforcement, 164
 - rejection, 105, 140, 142, 144, 145, 146, 147, 148, 149, 153, 154, 304, 376, 588
 - relationship marketing, 465, 467, 474, 487
 - relative size, 183
 - relatives, 169, 275, 276, 285, 286, 541, 544
 - relativity, 505
 - relaxation, 291
 - relevance, xii, 257, 307, 335, 356, 359, 367, 376, 380, 434, 454, 456, 540, 573, 591
 - reliability, xi, 186, 274, 319, 376, 379, 380, 382, 392, 397, 425, 467, 473, 474, 521, 542, 545
 - Reliability, 392, 401
 - relief, 455
 - religion, 280
 - religiosity, 400
 - renaissance, 347
 - rent, 354, 363
 - repetitions, 13, 342
 - replication, 252, 398, 402
 - representativeness, 356, 380, 532
 - repressed memories, 154
 - reproduction, 234
 - reptile, 491, 492, 495, 498
 - reptiles, 492, 495, 503, 505, 511
 - requirements, x, xiv, 113, 245, 253, 260, 263, 434, 470, 471, 551, 552, 553, 558
 - researchers, 63, 76, 97, 99, 119, 124, 126, 127, 128, 129, 131, 133, 134, 135, 138, 139, 143, 146, 148, 183, 200, 204, 221, 261, 264, 319, 327, 330, 346, 353, 368, 370, 377, 406, 407, 467, 518, 522, 573, 574
 - reserve capacity, 273
 - reservoir, 347
 - residential, 290
 - resistance, 103, 284, 317, 559, 560
 - resolution, 191, 440, 487
 - response time, 136
 - responsibility for learning, 261
 - responsiveness, 467
 - restaurant, 134, 254
 - restoration, 74
 - restructuring, 76
 - retention, 153, 183, 186, 250, 251, 252, 253, 257, 266, 270, 276, 429, 486
 - retention interval, 153, 183, 186, 276
 - retina, 233
 - retirement, 282
 - retrograde amnesia, 533
 - returns, ix, 227, 256, 327, 332, 335
 - RF, 289
 - Rho, 129, 155
 - rhythm, 115, 239, 302, 586
 - rhythms, 76, 497
 - rice, 469
 - right hemisphere, 166, 168, 192, 420, 434, 443, 453
 - right hemisphere hypothesis, 434, 453
 - right visual field, 443, 453
 - right-handers, 169
 - rights, iv, 198
 - rigidity, 380
 - rings, 410, 422
 - risk, x, xv, 160, 169, 232, 239, 295, 303, 304, 306, 383, 384, 388, 389, 427, 457, 469, 525, 531, 534, 572, 573, 574, 576, 577, 579, 587, 588, 590

risk aversion, 574
 risks, 470
 rivers, 470, 472
 RMSEA, 390, 391, 475
 Roads, 242
 robotics, 240
 Robotics, 113
 rodents, 406
 romantic involvements, 488
 Rome, 31, 33, 35
 root, 10, 15, 40, 44, 47, 56, 130
 roots, 569
 Roses, 531
 rotations, 422
 roughness, 429
 routes, 235
 routines, 261
 Royal Society, 463
 RP, 170
 rubber, 407
 rules, vii, 63, 64, 71, 72, 79, 80, 81, 82, 95, 107, 125, 346, 356, 357, 358, 360, 472, 516
 Russian, 27, 55, 60

S

saccades, 70
 sadness, 106
 safeguard, 471, 474
 safety, 31, 241, 282, 472
 salt, 10
 sample, x, xii, 3, 160, 167, 169, 170, 171, 218, 219, 245, 265, 266, 270, 274, 284, 297, 307, 312, 376, 381, 382, 390, 393, 398, 402, 403, 471, 472, 475, 481, 482, 518, 524, 545, 581, 591
 sampling, 481, 527
 sanctions, 471, 472
 sand, 10
 SAS, 309, 593
 SAT scores, 188
 satisfaction, 275, 284, 309, 359, 360, 469, 485, 487, 488, 576, 593
 saturation, 305, 589
 savings, 468, 576
 schema, vii, 63, 64, 71, 72, 73, 79, 80, 81, 82, 83, 84, 87, 95, 98, 107, 134, 187, 240, 254, 255, 257, 353, 354, 355, 357, 362, 363, 364, 369, 371, 376, 400, 425
 schemas, 64, 71, 135, 139, 256, 305, 376, 589
 schemata, xi, 80, 81, 349, 353, 362, 370
 schizophrenia, 504
 Schizophrenia, 241
 schizophrenic patients, 231, 280
 scholarship, 347
 scholarships, 312
 school, 2, 6, 182, 183, 192, 194, 269, 270, 271, 330, 381
 school failure, 269
 schooling, 381
 science, ix, x, 55, 59, 60, 61, 70, 165, 202, 227, 311, 312, 313, 315, 320, 329, 330, 335, 342, 344, 507
 scientific knowledge, 269
 scientific understanding, xiv, 567
 scope, xi, 349, 352, 355, 362, 367, 368, 369, 370, 471, 501, 570
 scores, 169, 188, 209, 214, 246, 265, 365, 380, 381, 394, 395, 396, 399, 438, 449, 453, 482
 scripts, 153, 255, 533
 SD, 171, 205, 209, 210, 214, 217, 314, 320, 321, 381, 393, 438, 449, 473
 SDS, 223
 SE, 173, 542, 543, 545, 546
 search, 52, 58, 59, 62, 77, 121, 123, 133, 151, 152, 153, 156, 168, 176, 182, 190, 193, 239, 260, 262, 264, 266, 267, 517, 564
 searches, viii, 121, 159, 177, 179, 180, 182, 243
 searching, 52, 88, 121, 170, 173, 176, 180, 183, 185, 246, 469
 security, 283, 472, 568
 seed, 10
 segmentation, 77, 103, 234, 485
 segregation, 120, 121, 411
 selecting, 13, 18, 52, 77, 100, 143, 354, 356, 363, 368, 571
 selective attention, 54, 88, 111, 113, 164, 307, 435, 436, 591
 Self, 63, 79, 85, 86, 114, 162, 192, 261, 274, 440, 441, 452, 461, 512
 self monitoring, 237
 self-awareness, 69, 92
 self-concept, 68
 self-consciousness, 64, 65, 82, 83, 85, 86, 108
 self-esteem, 264, 278, 282, 285, 286, 573
 self-image, 296, 300, 580, 584
 self-monitoring, 74, 308, 592
 self-regulation, 72
 self-report, xi, 291, 375, 380, 381, 382, 442
 seller, 486
 SEM, 486
 semantic association, 516
 semantic information, 148, 253

-
- semantic memory, xiii, 253, 273, 278, 373, 515, 516, 517, 522, 525, 527, 529, 530, 532, 534, 535
 - semantics, 2, 5, 6, 10, 13, 57, 60, 61, 83, 108, 154, 350, 366, 372, 374, 529
 - senescence, 167, 185
 - senile, 274, 287, 291
 - senile dementia, 274, 287, 291
 - sensation, 18, 43, 55, 74, 76, 78, 84, 98, 100, 102, 103, 109, 302, 507, 510, 586
 - sensations, 55, 74, 76, 77, 78, 80, 81, 82, 102, 105, 106, 107, 112, 303, 414, 497, 502, 587
 - sense organs, 75, 76, 78, 97, 229, 231
 - senses, xii, 51, 161, 239, 249, 250, 262, 282, 366, 405, 407, 412, 414, 415, 416, 418, 420, 425, 426, 430
 - sensitivity, 423, 470, 547, 573
 - sensorimotor system, 231
 - sensors, 104, 106, 107, 560
 - sensory experience, 510
 - sensory memory, 93, 248, 249, 259
 - sensory modalities, xii, 77, 249, 405, 408, 411, 412, 414, 416, 418, 420, 423, 424, 425, 429
 - sensory modality, 77, 419, 426
 - sensory systems, 506
 - sentences, 4, 18, 22, 24, 25, 26, 37, 39, 53, 56, 82, 89, 138, 213, 219, 300, 584
 - separation, xii, 10, 30, 40, 405, 418
 - septum, 496
 - series, 13, 16, 20, 33, 41, 48, 92, 118, 122, 124, 126, 133, 165, 174, 263, 301, 302, 304, 377, 396, 409, 410, 422, 423, 435, 468, 474, 542, 544, 553, 556, 559, 585, 586, 588
 - service industries, 487
 - service provider, 467, 474, 483, 484, 485, 487
 - service quality, 467, 469, 474, 475, 483, 485, 486, 487, 488
 - services, iv, xiii, 292, 465, 466, 467, 468, 470, 485, 486, 487, 488
 - set theory, 351, 352, 358, 362, 367, 370
 - severity, 282, 382, 483, 522, 523, 525, 535
 - sex, 161, 164, 165, 166, 167, 187, 188, 189, 190, 191, 192, 194, 195, 224, 307, 308, 524, 525, 529, 533, 534, 591, 592
 - sex differences, 164, 165, 166, 167, 187, 190, 192, 194, 195, 307, 525, 533, 591
 - sex hormones, 167, 191
 - sex steroid, 167
 - sexual abuse, 296, 309, 580, 593
 - sexual assault, 308, 592
 - sexual behaviour, x, xv, 295, 296, 306, 579, 580, 590
 - sexual dimorphism, 164, 192
 - sexual dysfunctions, 295, 296, 297, 300, 579, 580, 581, 584
 - sexual orientation, 191
 - sexual problems, 309, 593
 - sexuality, 193, 296, 303, 307, 308, 309, 580, 587, 591, 592, 593
 - SH, 291
 - shame, 453
 - shape, 18, 78, 86, 118, 121, 170, 174, 182, 186, 195, 301, 340, 341, 352, 363, 364, 406, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 424, 425, 428, 429, 430, 585
 - shaping, 195
 - shares, xii, 405, 538
 - sharing, 98
 - shock, 299, 301, 583, 585
 - shocks, 298, 299, 582, 583
 - short period, 249, 435, 454
 - short term memory, 249
 - shortages, 221
 - short-term, vii, 1, 9, 24, 58, 83, 94, 114, 234, 236, 240, 247, 248, 249, 250, 259, 291, 425, 565
 - short-term memory, 9, 24, 58, 234, 247, 248, 249, 250, 259, 565
 - shoulder, 411
 - showing, 44, 162, 168, 172, 176, 186, 220, 278, 284, 339, 343, 345, 434, 435, 444, 454, 494, 542, 547, 555
 - side effects, 78
 - sign, xi, 91, 230, 313, 319, 325, 332, 343, 346, 375, 384, 389, 392, 425, 457
 - signaling, 231, 487
 - signalling, 69
 - signals, 68, 69, 77, 97, 100, 101, 104, 105, 230, 302, 307, 435, 436, 455, 456, 502, 553, 586, 591
 - significance level, 394
 - signs, 5, 91, 239, 279, 301, 303, 313, 339, 425, 585, 587
 - similarity, 7, 49, 120, 129, 130, 138, 148, 149, 150, 151, 152, 327, 348, 355, 358, 416, 421, 502, 532, 533, 540
 - simulation, 167, 365, 366, 485, 538, 562, 563
 - simulations, 366
 - Singapore, 60
 - singular, 10, 13, 23, 29, 43, 325
 - Sixth Amendment, 198
 - skeleton, 54
 - skills, 160, 164, 166, 169, 186, 187, 189, 253, 270, 274, 280, 284, 290, 312, 320, 325, 329, 342, 344, 345, 407, 419, 467
 - skin, 10, 408, 416, 417, 552, 559, 560

-
- sleep, 10, 92, 97, 98, 171, 194, 503
 sleep disorders, 171
 smoke, 10, 34
 smoking, 34
 snakes, 439, 455
 snoezelen, 282
 social anxiety, 436, 463
 social behavior, 289, 503, 575
 social behaviour, 160
 social class, 160
 social cognition, 575
 social context, 189, 313, 571
 social development, 246
 social environment, 232
 social evaluation, 332
 social factors, 53
 social interactions, 549
 social isolation, 280, 282
 social phobia, 296, 304, 307, 376, 436, 461, 580, 588, 591
 social policy, 508
 social psychology, 150, 224, 462, 576, 577
 social relations, 304, 588
 social roles, 285, 525
 social sciences, 329, 490
 social support, 273
 socialization, 168, 188, 276, 280, 283, 284
 society, 168, 187, 246, 313, 340, 348
 sociocultural, 168
 socioeconomic, 472, 541, 544
 socioeconomic background, 541, 544
 socio-emotional, 264
 sociological, 313, 347, 348
 Socrates, 497, 502
 software, 56, 172, 175, 314, 315, 317, 441, 482
 SOI, 2, 3
 solid phase, 316
 solution, xi, 7, 28, 50, 52, 70, 229, 320, 376, 378, 383, 386, 387
 somatosensory, 64, 71, 73, 74, 78, 82, 84, 87, 95, 98, 429, 510
 sorting, 312, 496
 sounds, 23, 25, 55, 82, 83, 233, 331, 346, 414, 423
 South America, 493, 494
 SPA, 473
 space environment, 253
 spacetime, 502
 space-time, 279
 Spain, 60, 399, 433, 464, 465, 466, 471, 472, 473, 475, 477, 478, 481, 482, 483, 515
 spatial ability, 160, 164, 165, 166, 168, 169, 185, 187, 188, 192, 193, 229
 spatial information, viii, 159, 160, 161, 162, 163, 170, 177, 183, 185, 420
 spatial learning, 182, 192
 spatial location, 126, 127, 164, 185, 445
 spatial memory, 164, 166, 168, 170, 185, 188, 190, 192, 193, 195
 spatial processing, 194
 spatial representations, 190, 194
 spatiotemporal, 233
 specialization, 194, 257, 353, 354, 355, 357, 362, 364, 366, 367, 368, 369, 370, 406, 434
 species, 5, 25, 79, 185, 333, 406, 421, 495, 497, 505, 506, 539, 544, 547, 549
 specific knowledge, 256, 322, 531
 specificity, xii, 55, 76, 163, 186, 298, 307, 376, 379, 399, 400, 515, 517, 518, 522, 523, 525, 526, 527, 532, 533, 534, 564, 582, 591
 spectrum, 275, 331, 408, 505, 531, 564, 568
 speech, 4, 7, 15, 16, 20, 22, 23, 24, 27, 28, 30, 31, 33, 56, 57, 60, 81, 82, 83, 84, 107, 198, 224, 234, 317, 318, 330, 331, 332, 334, 339, 346, 370, 371, 406, 414, 426, 428, 429
 speech perception, 429
 speech sounds, 414
 speed, 78, 96, 101, 102, 113, 130, 174, 194, 233, 235, 236, 284, 304, 471, 524, 544, 559, 588
 spelling, 346
 spending, 484
 spheres, 56, 472
 spiders, 439, 455
 spinal cord, 494, 562, 563
 sponges, 497
 sporadic, 468, 517
 sports, 164, 232
 spouse, 275
 Spring, 486
 SPSS, 442
 SR, 289, 560
 S-shaped, 572
 stability, xii, 15, 70, 205, 229, 230, 322, 327, 365, 376, 379, 392, 397, 556, 558
 stabilization, 275, 284
 stages, 77, 90, 170, 247, 249, 258, 267, 279, 282, 286, 301, 323, 390, 435, 436, 444, 454, 522, 523, 529, 585
 STAI, 441, 442, 445, 448, 449
 standard deviation, 394, 396, 449, 453
 standard error, 177, 178, 179, 180, 181
 standards, 259, 384, 387, 397, 457, 570, 571

- statistical analysis, 84
 statistical inference, 534
 statistics, 403, 473, 475, 482, 527, 572, 577
 steady state, 101, 322
 stellate cells, 500
 stereotype, 575
 stereotypes, 360
 stereotypical, 164
 steroids, 166
 stiffness, 557, 558
 Stimuli, 88, 204, 519, 520
 stimulus onset asynchrony (SOA), 84
 STM, 248, 249, 250, 251, 252, 253, 263, 266
 stock, 250
 storage, 58, 111, 194, 247, 248, 249, 250, 252, 254, 258, 260, 261, 262, 264, 267
 stoves, 3
 strain, 296, 553, 580
 strategy use, 188
 stream of consciousness, vii, 6, 63, 64, 72, 83, 84, 85, 95, 107
 streams, 156, 160
 strength, 35, 202, 282, 283, 284, 309, 324, 361, 395, 397, 553, 593
 strength training, 283
 stress, x, xv, 5, 128, 134, 139, 228, 238, 282, 295, 296, 299, 301, 302, 303, 304, 305, 308, 318, 579, 580, 583, 585, 586, 587, 588, 589, 592
 striatum, 491, 499
 stroke, 563, 564, 565
 structural equation model, 225, 486
 structural equation modeling, 486
 Structural Equation Modeling, 401
 structuring, 330, 332, 333, 349
 students, x, xii, 165, 182, 203, 212, 222, 245, 246, 247, 251, 252, 256, 258, 259, 260, 261, 265, 266, 267, 268, 270, 283, 296, 312, 314, 342, 344, 347, 348, 376, 379, 381, 393, 438, 553, 574, 580
 style, viii, 159, 176, 183, 192, 224, 280, 573
 subcortical structures, 231, 552
 subdomains, 378
 subgroups, 187
 subjective, ix, 18, 32, 36, 43, 54, 55, 64, 69, 71, 75, 84, 91, 105, 106, 119, 142, 227, 234, 235, 237, 240, 302, 307, 308, 440, 441, 442, 445, 455, 504, 505, 513, 571, 572, 586, 591, 592
 subjective experience, 71, 91, 119, 303, 513, 587
 subjectivity, 240, 502
 subliminal perception, 84
 substances, 171
 substitution, 49, 507
 substrate, 73, 87, 99, 190, 499, 517, 555, 564
 substrates, 192, 428, 502
 subtraction, 31, 318, 338, 423
 success rate, 312, 323
 succession, 68, 83
 suffering, 280, 288, 295, 299, 303, 304, 305, 579, 583, 587, 588, 589
 suicide, 80, 363
 summer, 24
 Sun, 512
 superiority, 420
 superstitious, 399
 supplementation, 188
 supplier, 466, 468, 469, 474, 483, 487, 488
 suppliers, 466, 468, 469, 470, 472
 supply, 72, 78, 80, 97, 101, 337, 342, 343, 561
 surplus, 343
 surprise, 239, 240, 318
 survival, 72, 79, 81, 82, 84, 105, 108, 274, 282, 433, 437, 503, 524
 survival value, 433
 susceptibility, 576
 sweat, 552
 Sweden, 292
 switching, xiii, 155, 465, 466, 468, 469, 470, 471, 472, 474, 482, 483, 484, 485, 486, 487
 symbolic, 498, 503
 symbols, 33, 75, 120, 516
 symmetry, 365, 400
 sympathetic, 296, 297, 308, 309, 552, 561, 565, 580, 581, 592, 593
 sympathetic nervous system, 565
 symptom, xi, 376, 379, 396
 symptomology, 395
 symptoms, xi, xii, 274, 281, 289, 376, 379, 380, 381, 382, 394, 395, 396, 398, 399, 400, 402, 403
 synchronization, 83, 234
 synchronize, 234
 syntactic, 53, 59, 257, 367, 370
 syntax, 53
 synthesis, xi, 96, 231, 349, 350, 371, 408, 410, 416, 503, 505
 systems, xiii, 407, 408, 426, 427, 437, 462, 463, 489, 490, 498, 499, 500, 501, 504, 505, 508, 524, 531, 563, 564

T

- tachycardia, 455
 tactics, 240, 266
 tangible, 284

-
- TAR, 144
 target population, 456
 target stimuli, 92, 435
 targets, 77, 131, 132, 136, 137, 139, 140, 143, 144, 146, 147, 148, 149, 436
 task demands, 98, 109
 task difficulty, 188
 task load, 88, 97
 task performance, 552, 564
 taste, 105, 106, 282, 285
 taxonomy, 7, 109, 361, 504
 TE, 355, 383, 384, 385, 388, 389, 390
 teachers, 268, 269, 270, 271, 329
 teaching, 246, 250, 252, 253, 255, 268, 270, 277, 283, 313, 314, 315, 316, 320, 321, 329, 345
 team sports, 164
 techniques, 54, 125, 133, 141, 142, 144, 150, 250, 252, 261, 262, 263, 267, 275, 276, 277, 279, 281, 283, 285, 288, 297, 487, 527, 581
 technology, 56, 113, 233, 269, 524, 553
 teens, 275
 telecommunications, 466
 telephone, 245, 277, 352, 472
 telephone numbers, 277
 television, 224, 352, 364
 temperature, 43, 49, 313, 409, 424, 494
 tempo, 43, 115
 temporal lobe, 133, 517, 529, 533
 temporal window, ix, 227, 234
 tenants, 571
 tension, 328, 365
 territorial, 503
 test items, 136, 141, 143, 144, 146
 test scores, 188
 test statistic, 527
 testimony, 154, 205, 212, 224, 225
 testing, viii, 71, 120, 125, 130, 141, 142, 146, 159, 160, 170, 172, 173, 174, 175, 176, 177, 182, 184, 189, 200, 266, 320, 392, 415, 417, 474, 507, 538, 539
 testosterone, 166, 167, 188, 195
 Testosterone, 188
 testosterone levels, 168, 195
 test-retest reliability, xi, 376, 379, 392
 Texas, 117, 316, 347
 textbook, 315, 316
 textbooks, x, 311, 312, 315, 316, 317, 320
 texture, 120, 121, 352, 363, 408, 409, 412, 414, 415, 417, 418, 420, 422, 424, 428, 429
 thalamocortical system, 68
 thalamus, 68, 84, 99, 126, 491
 theoretical, 278
 theoretical approaches, 246
 theoretical support, 261
 therapeutic, 274, 276, 283, 287
 therapeutic interventions, 287
 therapist, 280, 281, 282, 285, 286
 therapists, 133, 276
 therapy, 279, 280, 281, 282, 286, 287, 288, 289, 290, 291, 292, 307, 308, 309, 400, 401, 402, 456, 591, 592, 593
 thermodynamic, 97, 102
 thermodynamics, 313, 316
 Thessaloniki, 489
 thinking, 9, 59, 77, 98, 99, 101, 134, 228, 239, 246, 254, 264, 266, 271, 300, 317, 357, 359, 363, 372, 383, 386, 389, 423, 458, 498, 568, 569, 571, 573, 575, 576, 584
 third dimension, 19, 326, 366
 thoracic, 496, 560
 threat, xi, xii, 185, 299, 307, 308, 375, 376, 377, 378, 379, 385, 386, 387, 391, 397, 398, 434, 435, 437, 455, 461, 462, 463, 583, 591, 592
 threatened, 298, 472, 582
 threatening, 433, 435, 436, 454, 455, 456, 462, 464
 threats, 183, 299, 583
 three-dimensional, 19, 170, 174, 191, 327
 threshold, 77, 80, 84, 91, 102, 233, 304, 471, 484, 510, 560, 588
 threshold level, 510
 thresholds, 201
 throws, xii, 433
 tiger, 516
 time periods, 88
 time-frame, 356
 timing, 222, 318, 510
 tip-of-the-tongue, 151
 title, 150, 505
 toddlers, 182, 191
 Tokyo, 60
 tolerance, 194, 471, 472, 482
 tones, 98
 tonic, 455, 555, 558
 tooth, 10
 top-down, 92, 93, 95, 118, 120, 122, 124, 125, 156, 238, 240
 topographic, 502
 topological, 410, 424
 toys, 164, 166, 169
 tracking, 54, 98
 tracks, 552
 trade, 104

trade-off, 104
 tradition, 2, 365
 traffic, 17, 97, 232, 235, 236, 237, 241, 471
 training, xiv, 92, 165, 170, 175, 184, 186, 245, 246, 271, 273, 274, 275, 278, 280, 281, 283, 284, 286, 288, 292, 552, 563, 574
 training programs, 186, 288
 trait anxiety, 434, 436
 trajectory, 315
trans, 35
 transcript, 317, 318, 319, 332, 339, 340, 342
 transcription, 317, 319, 346
 transcripts, 314, 317, 318, 323
 transducer, 553
 transduction, 232
 transfer, xii, 249, 251, 252, 266, 313, 344, 355, 405, 407, 408, 411, 412, 414, 415, 416, 417, 418, 419, 420, 424, 425, 427, 428, 429, 430
 transformation, 76, 100, 406, 500
 transformations, 312, 526
 transition, 111, 316, 323
 transitions, 175
 translation, vii, 1, 2, 3, 49, 53, 55, 56, 58, 59, 60, 115, 380, 382, 420, 421, 427, 502
 transmission, 233, 246, 249, 408, 561
 transport, 249, 262
 transportation, 235, 262, 274
 transpose, 305, 589
 trapezius, 553
 trauma, 304, 588
 travel, 161, 188, 233, 575
 treatment, 3, 171, 186, 187, 188, 194, 259, 260, 264, 274, 275, 278, 279, 280, 281, 282, 284, 285, 286, 288, 292, 308, 309, 358, 367, 402, 438, 456, 462, 467, 592, 593
 trees, 4, 525
 trend, 282
 triceps, 553
 triggers, 26, 253, 303, 587
 tropism, 497, 505
 trust, 487
 tuberculosis, 31
 turf cutter, 118
 tutoring, 339
 two-dimensional, 19, 170, 190, 315, 316, 325
 two-way, 365
 typology, 58, 577

U

UK, 109, 110, 115, 150, 152, 156, 347, 463, 515

uncertainty, xi, xii, 37, 246, 329, 342, 375, 376, 378, 379, 380, 385, 386, 387, 390, 391, 397, 398, 399, 472
 unconscious influence, xv, 567
 unconscious perception, 88, 112
 undergraduate, xii, 165, 283, 312, 314, 315, 321, 322, 339, 344, 376, 379
 undergraduates, 344, 382
 unemployment, 471
 unemployment rate, 471
 UNESCO, 246, 272
 unfolded, 328
 uniform, 5, 19, 97
 uninsured, 470, 471, 472
 United, 110, 111, 113, 114, 198
 United States, 110, 111, 113, 114, 198
 universal grammar, 53
 universality, 474
 university students, 212, 268, 270, 379
 unresolved conflict, 279
 unwanted thoughts, 383, 389, 457, 460
 updating, 82, 107, 188, 195
 upload, 507
 urine, 102
 Uruguay, 470
 USA, 2, 53, 60, 117, 197, 349, 378, 380, 464, 516

V

vagina, 297, 581
 vagus, 494
 Valdez, 187
 valence, 199, 200, 224, 434, 441, 444, 453, 454, 455, 456, 462, 573
 valence hypothesis, 434
 valenced information, 199
 validation, xi, xii, 282, 288, 292, 311, 376, 378, 381, 402, 464, 471
 validity, xii, 56, 202, 249, 291, 355, 357, 367, 373, 376, 379, 380, 382, 394, 395, 401, 473, 474, 482
 valuation, 154, 273, 347
 values, 2, 66, 68, 97, 215, 234, 253, 283, 305, 319, 322, 331, 337, 353, 356, 362, 363, 364, 379, 390, 392, 394, 395, 397, 442, 475, 482, 531, 543, 545, 554, 555, 559, 569, 572, 573, 589
 van der Waals, 316
 variability, 99, 234, 356, 522, 534, 565, 576
 variable, 274
 variable factor, 505
 variance, 213, 215, 234, 379, 386, 394, 395, 419, 442, 475, 482, 529, 542, 543, 545, 574

variation, viii, 19, 45, 63, 64, 74, 80, 100, 101, 106,
 107, 168, 202, 383
 variations, 77, 80, 106, 283, 297, 315, 323, 324, 331,
 345, 474, 552, 581
 varieties, 88, 91, 92
 varimax rotation, 383, 386
 vascular dementia, 530
 VC, 519, 520
 vector, 301, 585
 vegetables, 27, 517, 524, 525
 vegetation, 525
 vegetative state, 282
 vehicles, 92, 367, 368, 466, 471, 472, 517, 524, 525,
 539, 547
 vein, 529
 Venezuela, 270, 466, 470, 471, 472, 473, 475, 477,
 478, 481, 482, 483
 ventilation, 103
 venue, 198, 224
 verbal fluency, 188
 vertebrates, 491, 497
 vestibular system, 230
 victims, 286, 471
 Victoria, 311
 Vietnam, 304, 588
 vigilante, 463
 Viking, 512
 violence, 269
 violent, 383, 389
 virtual reality, 175, 186, 187, 193
 viscoelastic properties, 507
 visible, xi, 75, 173, 261, 311, 313, 332, 421
 vision, xii, 60, 70, 110, 113, 154, 156, 171, 232, 234,
 405, 408, 410, 411, 412, 413, 416, 417, 418, 419,
 420, 421, 424, 425, 427, 428, 430, 503, 539
 visual acuity, 413
 visual attention, 99, 110, 111, 113, 421, 435, 462
 visual environment, 126
 visual field, 25, 115, 121, 123, 124, 125, 189, 409,
 434, 435, 439, 443, 453, 454, 456, 464, 564
 visual images, 160, 414
 visual memory, 114
 visual modality, xii, 233, 405, 411, 412, 416, 422
 visual perception, 154, 407, 422
 visual processing, 539
 visual stimuli, 77, 441, 456
 visual stimulus, 234, 415, 419
 visual system, 230, 232
 visualization, 165, 167, 185, 552
 visuospatial, 189, 194, 273, 284
 vocabulary, 4, 42, 344

voice, 330, 331, 332, 334, 485, 488
 voice mail, 485
 voiding, 435
 volunteer work, 283
 vortex, 490
 vote, 206, 208, 213, 218
 vulnerability, x, xv, 295, 306, 399, 522, 579, 590
 Vygotsky, 313, 325, 348

W

waking, 101
 walking, 174, 235, 283, 406
 Wall Street Journal, 520
 war, 261, 315
 warrants, 248, 400
 Washington, 243, 271, 347, 373, 485
 water, 5, 10, 31, 43, 44, 102, 167, 187, 190, 195,
 440, 455
 water maze, 195
 weakness, 327
 wealth, 406
 web, 204, 304, 360, 588
 web-based, 204
 Weinberg, 290
 well-being, 285, 467
 wellness, 74
 Western culture, 165
 William James, 134
 wind, 10
 windows, ix, 28, 227, 235, 236
 wine, 6, 21, 32
 winter, 3
 withdrawal, 105
 wood, 3, 17
 word frequency, xiii, 515, 521
 word meanings, 372
 word perception, 154
 word processing, 175
 word recognition, 112
 workers, 473, 524
 working memory, x, xv, 22, 24, 25, 57, 61, 64, 71,
 73, 74, 76, 78, 84, 87, 93, 95, 96, 98, 108, 155,
 187, 188, 193, 194, 266, 295, 305, 306, 408, 410,
 579, 589, 590
 workplace, 232
 worm, 10
 worms, 359, 455, 497
 worry, xi, 376, 379, 399
 writing, 12, 24, 205, 246, 286, 314, 319

X

X-axis, 146

young adults, viii, 159, 171, 177, 178, 179, 180, 181, 182, 183, 184, 185
young people, 185

Y

Y-axis, 146, 147
yield, 68, 146, 162, 286

Z

zero-risk, 232
Zn, 230